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ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

PROJECT NO. 2 - OPERATIONS AT HIGH TEMPERATURES

Report On

Sub-Project No. 2-11, Influence of High Temperatures on the Efficiency of Personnel

Sub-Project No. 2-12, Study of Methods of Attaining and Maintaining Acclimatization to High Temperatures

Sub-Project No. 2-13, Effect of Training on the Efficiency of Performance at High Temperatures

Sub-Project No. 2-17, Study of the Physiologic Effects of High Temperatures

SUBJECT: - STUDIES OF MEN IN SIMULATED DESERT HEAT

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ARMORED FORCE MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Project No. 2 (2-11, 2-12, 2-13,
2-17)

April 3, 1943

File No. 727-2

Report On

STUDIES OF MEN IN SIMULATED DESERT HEAT

1. PROJECT: 2; 2-11, Influence of High Temperatures on the Efficiency of Personnel; 2-12, Study of Methods of Attaining and Maintaining Acclimatization to High Temperatures; 2-13 Effect of Training on the Efficiency of Performance at High Temperatures; and 2-17, Study of the Physiologic Effects of High Temperatures.

a. Authority - Letter, Commanding General, Headquarters Armored Force, Fort Knox, Kentucky, File 400.112/6 GNOHD, dated September 21, 1942.

b. Purpose - The purpose of these experiments was to study, under controlled conditions in the laboratory hot room, the behavior of men when exposed to high temperature, (as implied by the sub-project titles), and to enlarge upon the information obtained in previous studies in the California desert (Report on Desert Field Study, Project 2-8, File No. 724.3, October 20, 1942, and report on Water & Salt Requirement for Desert Operations, Project No. 2-6, File No. 333.34, November 12, 1942.).

2. DISCUSSION:

a. General. Four acclimatization experiments, utilizing a total of fifty-six enlisted men, were carried out in the hot room of the Armored Force Medical Research Laboratory. The studies extended over a period of four months; some men being under study for a week; a great majority of the men for periods of from one to two months. Forty-eight men lived in the hot room continuously throughout the duration of the experiments, being permitted to leave for only two 5-minute periods daily.

b. Procedure: Temperatures like those encountered during the hot months in the California desert were used; 120°F during the day (0800-1700 hours) and 90°F at night. The relative humidity ranged from 15% to 22% during the day. Detailed accounts of the test procedures and the results are given in the Appendices.

3. CONCLUSIONS:

a. Acclimatization.

(1) Soldiers exposed to desert heat become adapted to it by a process of acclimatization which enables them to carry out their duties more efficiently and with less risk of illness from heat than when first exposed.

(2) The condition of men in respect to their ability and fitness for their tasks in the heat can be estimated by a careful observer who knows what to look for. Using the information in Appendix I, line officers who know the work capacities of their men, can determine their degree of acclimatization and whether or not it is safe for them to continue activity.

(3) A man acclimatized to heat works in the heat with a lower body temperature, lower heart rate and a more stable blood pressure, than when not acclimatized. (Appendix II, Chart 1) Nevertheless, acclimatization to heat cannot be measured by these criteria alone. (Appendix II, Chart 2) Changes in pulse and temperature accompany acclimatization but do not necessarily correlate with the man's behavior and ability to work. The man as a whole must be considered and evaluated.

(4) Acclimatization begins with the first exposure. The process is rapid and a major proportion of the acclimatization is acquired by the third or fourth day. (Appendix II, Chart 3)

(5) Soldiers in good physical condition acclimatize more quickly and are capable of a greater work output in the heat than are men in poor physical condition. (Appendix II, Chart 4)

(6) Continued training in cool environments beyond that necessary to attain good physical fitness does not further increase the ability to work in the heat nor shorten the period of acclimatization. (Appendix II, Charts 5, 6)

(7) Resting for three or four days in the heat, with activity limited to that required for subsistence, results in definite, but only partial acclimatization. Some work in the heat is necessary for complete acclimatization. (Appendix II, Charts 5, 6)

(8) When work is begun with first exposure to the heat and progressively increased within the limits of tolerance of the man, full acclimatization (the ability to perform a maximum amount of strenuous work in the heat) is attained most quickly. (Appendix II, Charts 5, 6)

(9) Strenuous work on first exposure to the heat is not well tolerated and will often result in disability. Continuing such a degree of work for another day or two will incapacitate many men - the few who can continue their labors do so ineffectively and inefficiently. (Appendix II, Chart 7)

(10) Excessive work on first exposure, even leading to heat exhaustion, does not, however, retard the rate of acclimatization or lessen the degree which is finally attained, provided work is discontinued upon the appearance of symptoms; water and salt are given; and work when later resumed is in keeping with the tolerance of the soldier. (Appendix II, Charts 7, 8)

(11) Three or four exposures to heat of 3 or 4 hours duration with two one-hour work periods during each exposure, will produce a considerable degree of acclimatization. These exposures may be separated by intervals of two days in a cool environment. (Appendix II, Chart 9)

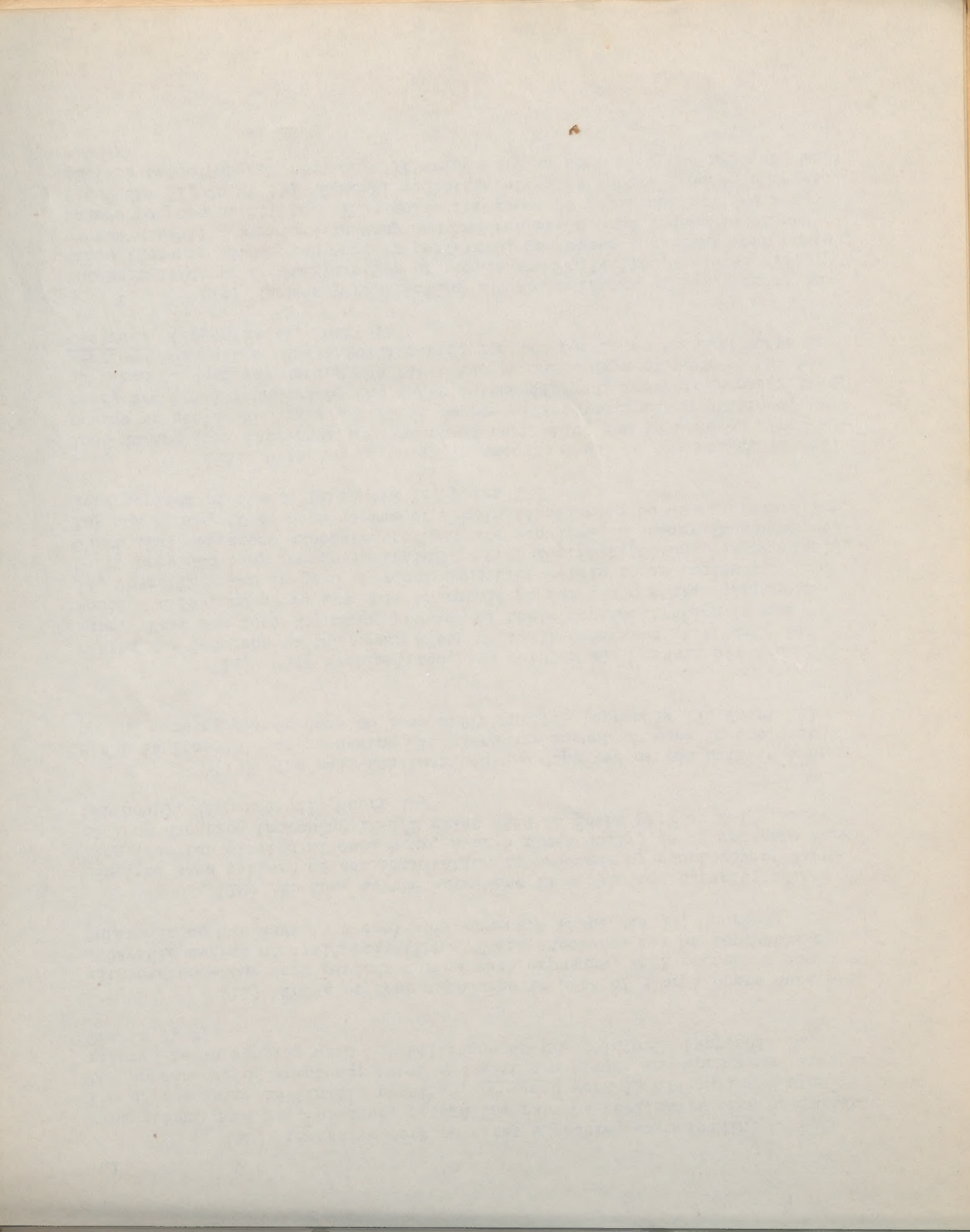
(12) So long as the work done is within the capacity of the man, the same pattern of acclimatization is produced by short severe exertion (for ten minutes of each hour, 4 or 5 times daily) as by moderate work of long duration (marching 12-1/2 miles with 20 pound pack at 2-1/2 miles per hour). (Appendix II, Chart 10)

(13) The well-acclimatized man deprived of adequate rest at night is incapable of producing his customary amount of work in the heat on the ensuing day or does so less efficiently. (Appendix II, Chart 11)

(14) Once acclimatized, the soldier will retain his adaptation for from one to two weeks after which it decreases at a variable rate. Most men lose the major portion of their acclimatization in one month - a few, however, are able to retain it for two months. (Appendix II, Chart 12) Men in good physical condition retain their acclimatization best, provided they remain in training after acclimatization. (Appendix II, Chart 12a) Repeated exposures to heat are required at intervals not exceeding one month, if a high degree of acclimatization is to be maintained for long periods of time. (Appendix II, Chart 13)

(15) Drinking of water in amounts equal to the weight (sweat) lost during work increases the amount of work which can be done on first exposure to heat. The rate and final degree of acclimatization attained, however, are not influenced by the water intake (forced, moderately restricted, or taken as desired) during the first two or three days of work in the heat, provided that after this initial period men are permitted as much water as desired. (Appendix II, Chart 14)

(16) Suddenly restricting the water intake of men working in the heat leads to a deterioration of morale and motivation, reduces greatly the efficiency with which work is performed, decreases the total work output, causes disabling symptoms in many men and renders others incapable of sustained purposeful action. This holds for even the well-acclimatized man. (Appendix II, Chart 15) Gradual reduction of water intake induces changes similar to sudden restriction, differing only in that they are produced more slowly.



(17) Acclimatization to hot dry (desert) environments increases markedly the ability of men to work efficiently and effectively in hot moist (jungle) environments. (Appendix II, Chart 16)

4. RECOMMENDATIONS:

a. Troops brought to a hot desert should when possible be given at least a four day period for acclimatization, during which time they should be supervised carefully by medical, line and non-commissioned officers.

b. Graded amounts of work should be done during acclimatization with regulated exposure to heat during the midday hours (Appendix I, Schedule 1).

c. Enough water should be drunk to satisfy thirst at all times. If more water is drunk during the first three days than is dictated by thirst alone, work will be accomplished more efficiently.

d. Unnecessary exposure to sun should be avoided. It increases the water requirement, adds to the danger of heatstroke and may cause serious sunburn.

e. All personnel should be familiarized with the signs and symptoms of heat exhaustion and should be instructed in methods of emergency treatment (Appendix I).

f. All officers should be made familiar with the water and salt needs of their men and be acquainted with the information given in the Appendices.

g. For one week before and after entry into a hot desert troops should be given adequate rest and alcohol should be prohibited. Men who have had recent illness should not be exposed to heat until they have completely recovered (and are back in good physical condition).

Prepared by:

Captain William B. Bean
Lieutenant Ludwig W. Eichna
Major William F. Ashe
Captain S. M. Horvath
Captain Norton Nelson

APPROVED

Willard Machle

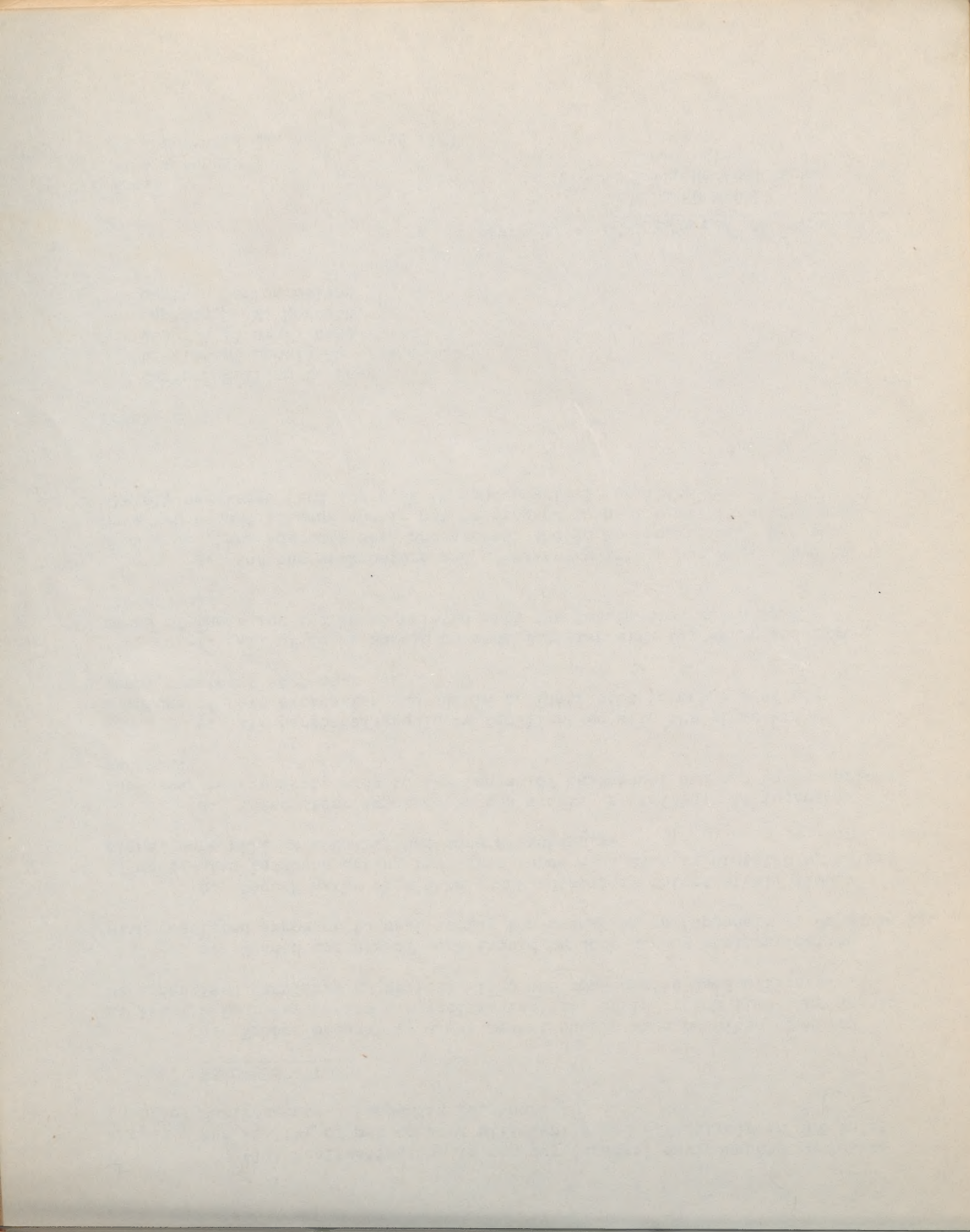
WILLARD MACHLE

Lieut. Col., Medical Corps
Commanding

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#1 - Appendix I

#2 - Appendix II, with Charts (17)



APPENDIX

GENERAL RECOMMENDATIONS FOR SUPERVISION OF TROOPS IN HOT DESERTS

1. Schedule of graded work during acclimatization

Gradually increasing amounts of work should be done during the acclimatization period, with limited exposure to heat during the mid-day hours. A schedule set up according to the following plan with alternating rest and work periods is safe for practically all men; it provides for work during the cooler morning hours and in the hot afternoon hours. Local and regional variations may call for slight modifications. During the midday period the men should rest and keep in the shade as much as possible.

Proposed Schedule of Work During Period of Acclimatization
When Maximum Air Temp. is 90 to 105°F When Maximum Air Temp. is 105°F and Over
Hours of Work

First Day	0700 - 0900 and 1500 - 1700	0800 - 1000 and 1500 - 1600
Second Day	0700 - 1000 and 1430 - 1630	0700 - 1000 and 1500 - 1600
Third Day	0700 - 1000 and 1400 - 1700	0700 - 1000 and 1400 - 1600
Fourth Day	0700 - 1100 and 1330 - 1750	0700 - 1000 and 1330 - 1630
Fifth Day	Regular Duty	0700 - 1100 and 1330 - 1630
Sixth Day	Regular Duty	Regular Duty

The working period should be divided so that a man works and rests in alternating half-hour periods. Two teams can be arranged to work in sequence. The work should equal that of marching with a 20 pound pack at the rate of 2.5 miles per hour. Lighter work may be carried out for longer, and heavier work, for shorter times.

2. Symptoms of Heat Exhaustion.

Symptoms of heat exhaustion should serve as a warning to cease work immediately and lie down - if possible in a shady place. Plenty of water should be drunk. These warning symptoms are: flushed face, headache, dizziness, irritability, shortness of breath, nausea, occasionally vomiting and sometimes abdominal cramps or cramps in the muscles. A man in danger of imminent collapse can often be recognized by his flushed face, weakness, incoordination or stumbling gait.

Incl #1

When a man has collapsed from the heat, first-aid treatment should be given as follows: The following steps should be taken, in the order named:

- a. Put the man in the shade.
- b. Send for a medical officer and an ambulance.
- c. Remove the man's clothing and sponge the body with water, fanning vigorously to help evaporation.
- d. Give cool, salted water to drink, if it can be retained.

For a day or two before prostration a soldier may appear below par and have a poor appetite. Men showing these early effects of heat should be given plenty of water and adequate salt and be relieved of work until they have recovered.

4. Physical Characteristics in Relation to Heat Tolerance.

For protracted missions or when water is restricted, men with the following characteristics will do best:

- a. Physical characteristics - men of below average to average stature, preferably of the lean, wiry type, having a low ratio of body mass to surface area. Large stocky and fat men perform at a much poorer level.
- b. Age - between 20 and 30 years.
- c. Physiologic characteristics - capable of working strenuously in natural or artificial hot environments without great rise in body temperature or pulse rate and without complaints.
- d. Physical condition - maximum physical fitness is essential.

Sheet #1

APPENDIX II .

A. EXPERIMENTAL CONDITIONS AND PROCEDURES

1. Environment - Air temperature during the day (0800 hours to 1800 hours) 120°F, during the night (1800 hours to 0600 hours) 80°F; relative humidity constant, 15% and 35% during the day and night, respectively. The air was required to change from one temperature to the other. Wall and floor temperatures were in equilibrium with air temperatures. No additional radiant heat was supplied and the environment, therefore, was not as severe as that of a desert with identical temperature and humidity. Two sources of heat-gain present in the desert were lacking in this experiment; (a) the radiant heat of the sun, (b) the heat from the desert terrain which reaches 140°C to 160°F. A moderate degree of air movement was obtained by means of two 26-inch fans or four 10-inch fans. The rate of air movement was not measured.

Since the studies were carried out during five winter months, the experimental environment represented an extreme change in environment for the subjects.

2. Experimental subjects - 56 enlisted men (42 lived continuously in the hot room, 8 lived in barracks, reporting to the Laboratory for exposure periods. The age limits of the men were 17 and 43 years, but the majority were between 20 and 28 years.

3. Clothing - Men wore what they chose; during the hot periods, only cotton shorts, shoes and socks; during the preliminary cool periods, regulation fatigue clothing.

4. Preliminary training - Men were being adjusted to the hot environment. All men worked in cool temperatures (70°F to 76°F) for one week. During this period their work was the same as that which they were to perform later in the heat. This procedure accustomed the men to the work and experimental procedures, and produced a very uniform state of physical fitness in all men.

5. Activity in the hot environment - For test purposes the men were divided into three groups according to activity:

Group I. Resting.

The men in the resting group were permitted to rest for 3 or four days in the heat before beginning work.

End of

The men in the bicycling group performed strenuous work for short periods; pedalling a stationary bicycle for ten minutes each hour, five times a day.

Group III..Walking.

The walking group was the largest of the three. These men performed work of moderate severity for long duration, namely, walking at a standard army pace while carrying a 20 pound pack. A walk of 10 to 13 minutes was given between successive work periods. Unless disabled, the men walked two successive periods in the morning and three in the afternoon, walking a total of 12-1/2 miles a day. The data and conclusions of this report are based for the most part on observations made upon men performing this type of work. Certain exceptions are mentioned in the text.

The eight men who lived in their barracks were subjected to the hot environment for 4 hours in the morning, returning to their quarters after each exposure. During each exposure to heat they walked for two work periods, separated by a rest period of one hour. All eight men had their initial exposures on the same day. They were then divided into pairs for re-exposure. At intervals of three days a new pair was re-exposed to the heat. Once a man had received his second exposure to the heat he returned to the hot room every third day until acclimatized.

6. Food - Regular army fare obtained from their regular mess. No record was made of the type or amount of food eaten.

7. Water - Salt was added to the drinking water (final concentration 0.2%). The water intake was controlled in one of three methods:

- a. As much as desired, whenever wanted.
- b. Intake regulated to equal the total weight lost.
- c. Restricted to 4 litres, approximately one-half of the needed intake, and given in either of two schedules: (1) 270 ml every hour from 6:00 A.M. to 6:00 P.M., plus 750 ml from 6:00 P.M. to 6:00 A.M. (2) 750 ml at 6:00 A.M. 1250 ml with noon meal, 1250 ml with evening meal and 750 ml from 6:00 P.M. to 6:00 A.M.

8. Sleep - Eight to nine hours a night. A few men had difficulty sleeping on the first night of an experiment; but slept well throughout.

9. Observations made each morning on awakening - rectal temperature, pulse and respiratory rates, weight ($\pm 1/4$ pound), and measurement of the urine voided in preceding 24 hours.

10. Observations and during the work periods:

a. General appearance - noted continuously and records kept of vision, functioning of the hand, breathing, circulation, and complaints of gastro-enteric or cardiovascular disturbances.

b. Body temperature - rectal temperatures were taken at the beginning and end of each work period.

c. Heart rate - at the beginning and end of each work period with the subject in both the supine and erect position (3 minutes in each) and at 15 minute intervals during the walking period (subject marking time). Auscultation over the precordium was necessary to determine the more rapid rates.

d. Blood pressure - at the beginning and end of each work period with the subject both supine and erect (3 minutes in each position). Change of posture was obtained by means of a tilt table and also by voluntary movement by the subject.

e. Weight - the weight within 5 grams was recorded at the beginning and end of the two morning and three afternoon work periods. Subjects were naked and the sweat dried off.

f. The water intake and urine output during each work period and during each 24-hour period.

11. Special observations made at intervals throughout the studies included:

- a. Basal metabolic rate (Sanborn)
- b. Electrocardiogram
- c. Vital Capacity
- d. Code aptitude tests
- e. Attention tests

Encl # 2

Work in hot environments is at first difficult or impossible for most men. By a process of acclimatization, however, man adapts himself to work in the heat. He then works without subjective complaints and with little or no disturbance of bodily functions. Acclimatization to heat appears to be a complex physiologic readjustment which cannot be adequately defined or completely determined by a few simple physiologic measurements. Nevertheless, this adaptation is accompanied by certain physiologic changes which serve as general indices of the whole process. In this report some of these physiologic changes are discussed and represented by a series of charts.

All charts are similarly plotted (see Chart 1). Along the ordinates heart rate, rectal temperature and blood pressure are charted in turn. The total height of the column indicating blood pressure represents the systolic pressure; the white portion of this column (limited by the transverse line) indicates the diastolic pressure; the solid or hatched portion of the column gives the pulse pressure. Along the abscissae are indicated the day of work, the environment in which the work was performed and the period of work at the end of which the plotted data were obtained. For example, in Chart 1 the first pair of columns represents the data obtained in the erect and supine positions at the end of the fifth work period on the 4th day in the cool environment; the next pair of columns, the data at the end of the second work period on the first day in the hot environment. Then, in turn, the data at the end of the third work period on the second day in the heat; at the end of the fourth work period on the third day in the heat and so on. A key with each chart interprets the hatching of the columns. The text associated with each chart indicates whether the data were obtained from single observations or averages.

1. Physiologic changes (Charts 1, 2)-

The acclimatized man works in the heat with a lower pulse rate, a lower body temperature and a more stable blood pressure after change in posture than when not acclimatized (Chart 1). Compare, for example, performance on the fifth and first days in the heat. In the unacclimatized state (first day in heat) change of posture causes marked alterations in cardiovascular dynamics, as indicated by pulse rate and blood pressure. In the erect posture the heart rate is markedly accentuated, the systolic blood pressure falls and the pulse pressure narrows. In Chart 1 compare the solid black (erect) and hatched (supine) columns. As a result of the lowered blood pressure the cerebral circulation at times becomes inadequate, symptoms of cerebral hypoxia arise and even syncope may ensue. Lying down promptly slows the heart rate, restores the blood pressure and dispels the symptoms of cerebral ischemia.

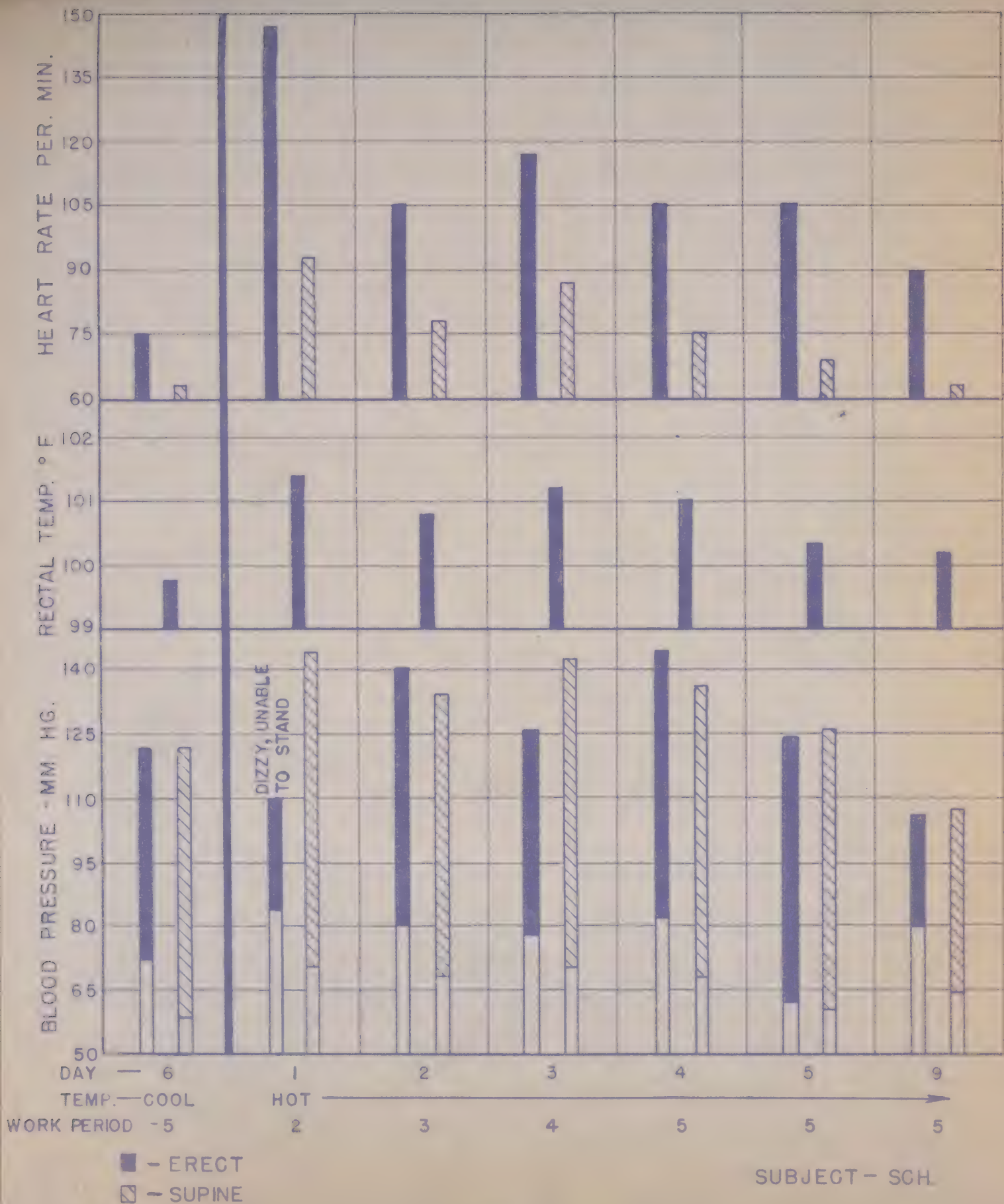


CHART - I



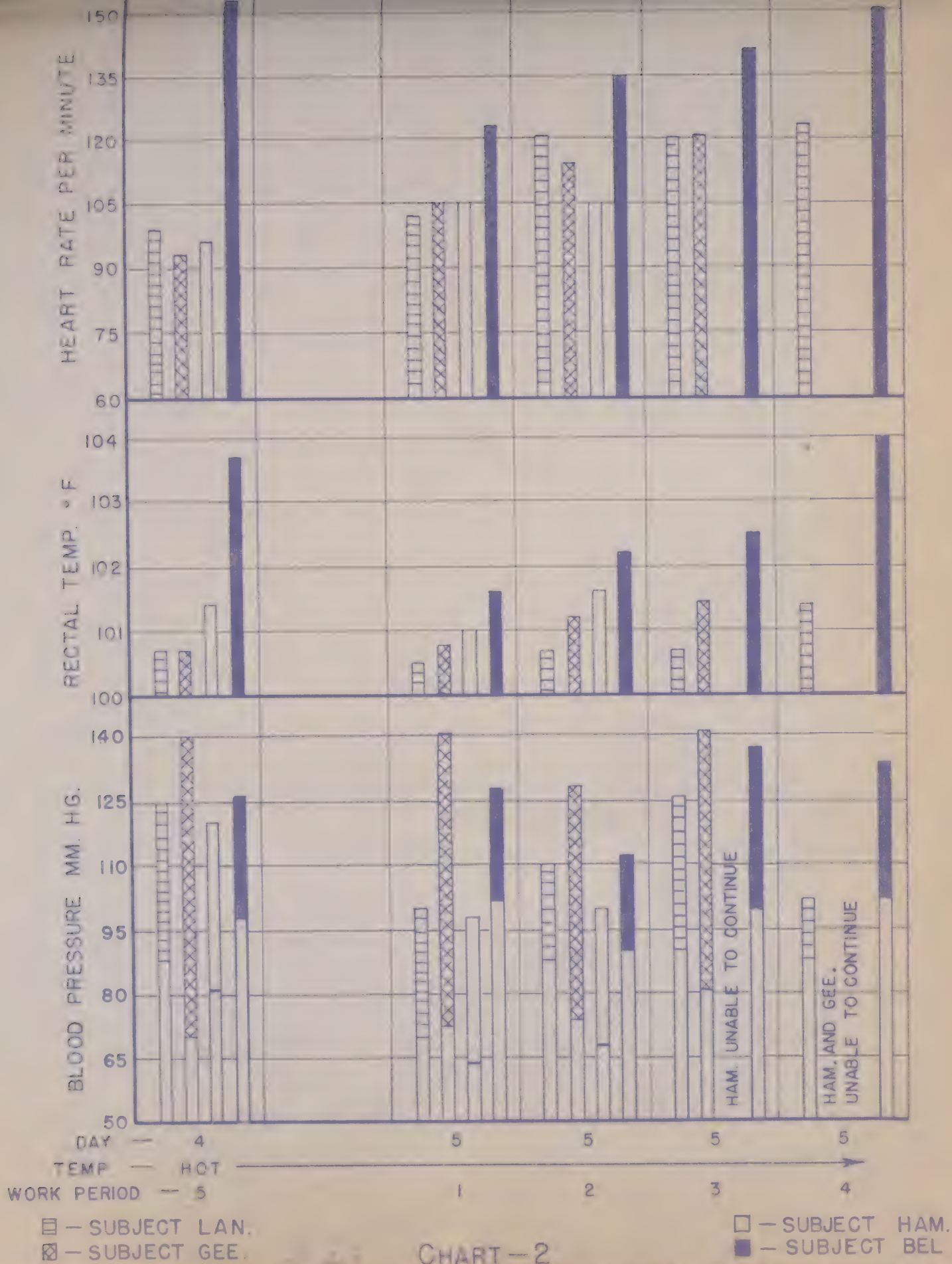
With continued exposure to heat, acclimatization progresses and the heart rate, rectal temperature and blood pressure return to levels approximating those obtained after similar work in cool environments. This is true with the subject erect or supine (Chart 1).

Although observations were made with the subjects both erect and supine, in this report acclimatization was evaluated for the subjects chiefly in the erect posture and all charts (unless otherwise indicated) refer to such measurements. Three facts led to this decision; (a) the findings in the erect posture paralleled those in the supine, (b) the erect posture places an added strain on the physiologic functions of man, revealing disturbances not apparent in the supine position, (c) a useful man is a working man; work usually requires the upright posture.

Although a low heart rate, a low rectal temperature and a stable blood pressure generally accompany acclimatization, one cannot define the process nor detect differences in the degree of acclimatization between individuals by such simple measurements alone. This is illustrated by the data for four subjects plotted in Chart 2. On the fourth day of exposure to heat all four men successfully completed five work periods at which time subject Bel. had the most rapid heart rate and the highest rectal temperature. This might be taken as an indication of incomplete acclimatization and evidence that Bel. was not as capable of work in the heat as the other three men. His general appearance and behavior, however, indicated that he was more fit than Ham. or Gee., both of whom had lower heart rates and body temperatures. On the following (5th) day, the men worked under more severe conditions. Subject Ham. became weak, nauseated and vomited after the second work period and could not continue. Subject Gee. was forced to stop at the end of the third work period because of exhaustion. Subject Bel. with a heart rate and rectal temperature which were always higher than those of Ham. or Gee., continued energetically for another work period and on the basis of heart rate and rectal temperature alone did not agree with the actual performance of these men.

Undoubtedly a man, doing a given amount of work, is less efficient and more prone to disability when his rectal temperature and pulse rate are high, than when they are low. Individual performance is influenced by many variables which are not evaluated by such simple measurements. It is necessary to consider and evaluate each man as a whole and to avoid focussing attention on the rectal temperature or heart rate. The man's subjective symptoms, his objective appearance, his behavior and his actual performance must receive at least equally careful consideration in any evaluation of his capacity to work in the heat.

Incl # 2





2. Symptoms and signs -

The acclimatized man is alert, performs his work energetically and without symptoms. Usually his heart rate and rectal temperature are low, at least not markedly elevated. On the other hand the unacclimatized man working in the heat becomes dull and apathetic, performs his work poorly, has a rapid heart rate and a high rectal temperature and may manifest to varying degrees and either singly or in combinations, the symptoms and signs of heat exhaustion. In the present experiments these symptoms and signs appeared in the following order of frequency: Symptoms (1) fatigue (2) headache (3) dizziness, especially when erect (4) shortness of breath (5) loss of appetite (6) nausea (7) vomiting (8) abdominal cramps; Signs (1) flushing of face and neck (2) rapid pulse rate (140 - 200/min) (3) lack of coordinated effort (clummy, stumbling) (4) staring glazed eyes (5) mental disturbances (apathy, poor judgment, irritability) (6) fever over 102°F (7) collapse.

Of interest is the marked flushing of the face, neck and upper chest which occurs in most men when they first work in the heat and which disappears as acclimatization develops.

ACCLIMATIZATION TO HEAT

As pointed out above, when different individuals are compared, the heart rate, rectal temperature and blood pressure are not in themselves completely reliable determinants of acclimatization to heat. Nevertheless, they may be utilized as indices of acclimatization when they are consistent with the other above-discussed evidences of acclimatization. It was with these limitations in mind that the heart rate, rectal temperature and blood pressures were used as indices in this study. The factors involved in attaining and maintaining acclimatization to heat are presented in a series of charts and it is to be understood that the plotted changes in rectal temperature, pulse rate and blood pressure were consistent with the picture of the man as a whole. When they were not, specific mention of the differences are made.

1. Course of acclimatization (Charts 1, 3) -

The process of acclimatization appears to be initiated by the first exposure to heat. This is indicated by Chart 1, in which are plotted the observations made on one man at the close of the last work period of each charted day. Considerable improvement in heart rate, rectal temperature and blood pressure (in the erect posture) is apparent on the second day in the heat, that is, after one day of previous exposure.

At the close of the last (second) work period on the first day in the heat this man was very tired, giddy and unable to stand erect. On the second day he finished three work periods feeling much better than on the previous day, had no difficulty in standing and maintained a normal blood pressure in the erect posture.

In most men, a major portion of the acclimatization to heat is attained by the fourth or fifth day of work in a continuously hot environment. This is illustrated in Chart 3 which shows the progressive changes recorded in two groups of men exposed to heat at different times. Each column represents the average of the data obtained on four men at the end of the last work period of the day indicated. During the first three to four days there is a progressive and rapid improvement in heart rate and rectal temperature, which thereafter levels off at values somewhat higher than those obtained under similar circumstances in the first exposure.

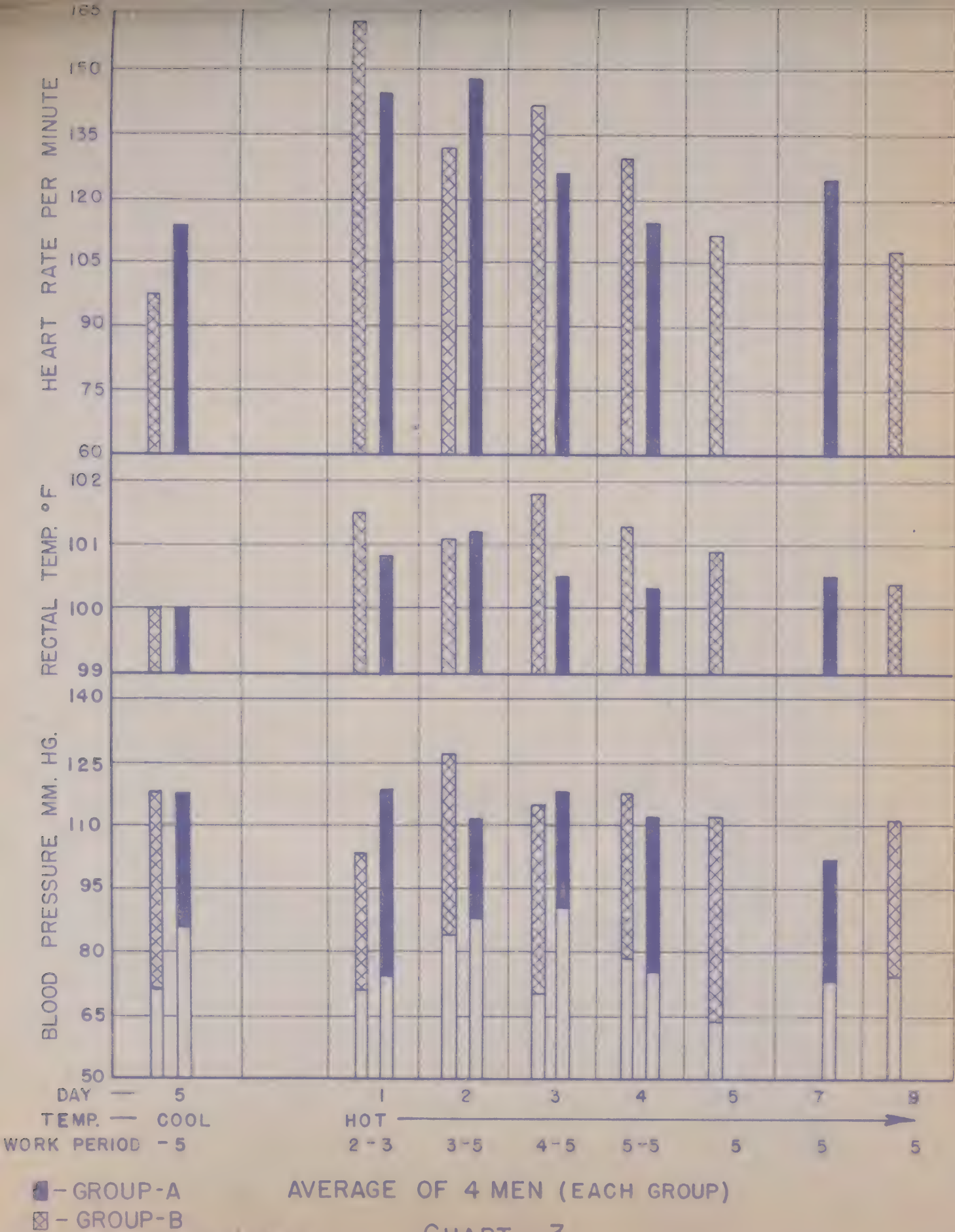


CHART-3

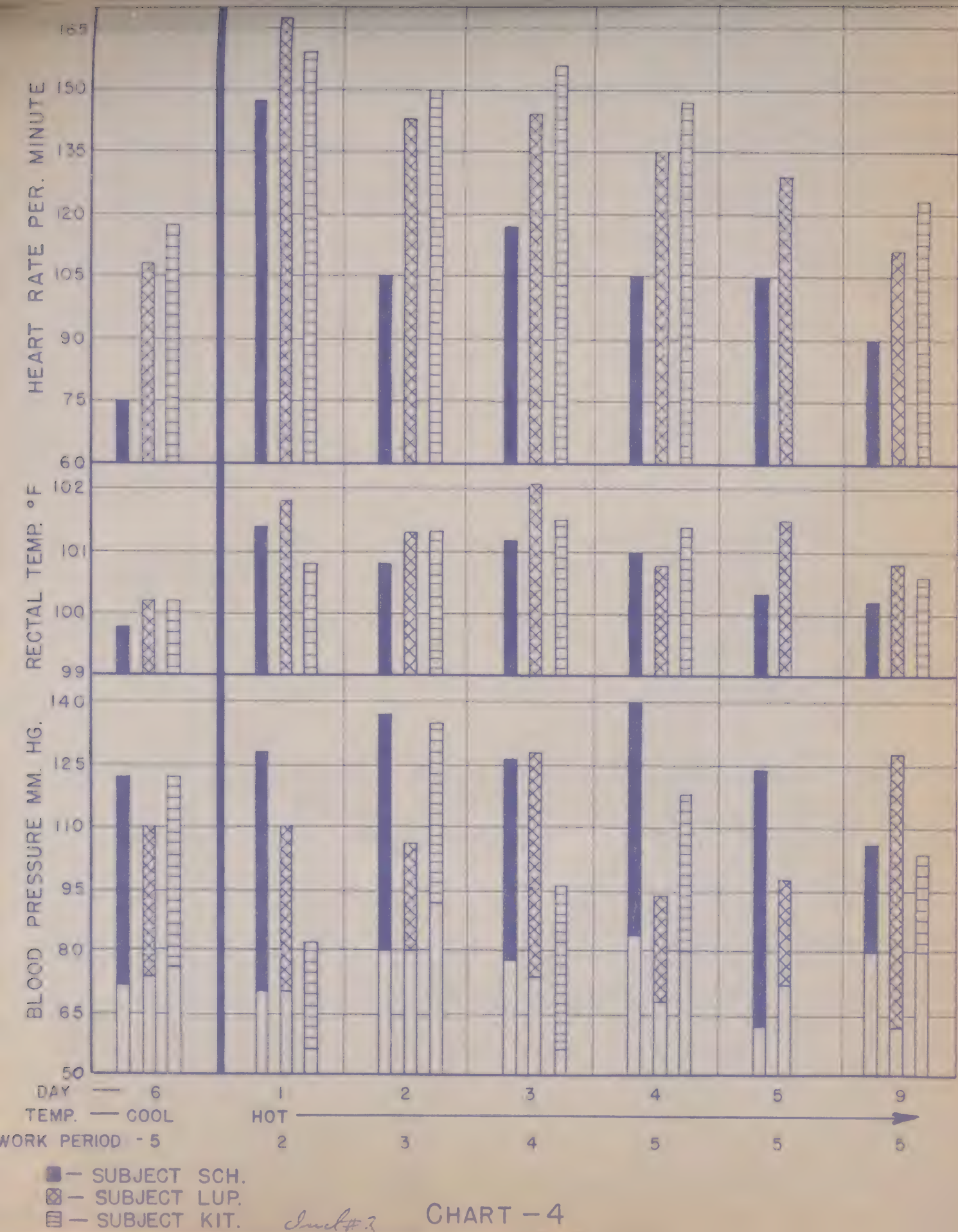


2. Physical condition (Chart 4) -

Although exceptions are not unusual in individuals, men in good physical condition generally acclimatize to heat more rapidly than men in poor condition. Moreover, the more fit men are capable of a greater work-output in the heat with less symptoms and less disturbance of their heart rates, rectal temperatures and blood pressures than are the less fit men. In this study the determination of physical fitness was based on the work performance of the men while in a cool environment. In evaluating physical fitness all of the factors previously discussed (the appearance and behavior of the men as well as the results of physiologic measurements) were taken into consideration. Those men were considered most fit who performed the prescribed work easily and energetically, without symptoms and with least disturbance of their heart rate, blood pressure and rectal temperature.

The three men whose records are compared were from a group of eight men whose physical fitness was assessed before they entered the hot environment. Three different observers gave independent ratings. All three observers placed subject Sch. first. Two observers placed subject Kit. seventh, one observer sixth. Two observers placed subject Lup. fifth, one observer second. Of the three men, Sch. was considered most fit, Kit. least fit, and Lup. intermediate between the two.

Observations on each of these three men were obtained at the end of the last work period of each of six days in the hot environment and, for comparison, the same measurements taken on the last day in the cool environment are also shown in Chart 4. The more rapid improvement in the pulse rate and rectal temperature of subject Sch. is readily apparent. An equally rapid improvement was also apparent in the general appearance and behavior of this subject. By the second day he was walking easily and with vigor. Note also the maintenance of blood pressure when erect. In contrast to Sch., the pulse rates, rectal temperatures and blood pressures of subjects Kit. and Lup. returned more slowly toward control levels. This was confirmed by the appearance of the men, especially Kit., who always seemed to be working with difficulty. Even after acclimatization had been attained by all three men the performance of Sch. was superior to that of the other two men (see 9th day in hot environment). On the fifth hot day subject Kit. was prevented from walking by blisters on the feet.



3. Activity prior to and during acclimatization (Charts 5, 6) -

Continuing the preliminary training period in a cool environment beyond that required to develop a satisfactory state of physical fitness does not increase the subject's tolerance to heat on first exposure. Resting in the heat for the first three days produces a definite tolerance to work in heat but the acclimatization thereby induced is only partial. Acclimatization is developed most rapidly by the daily performance of work in heat from the outset, the amount of work being progressively increased within the tolerance of the individual.

The relative effect of these three factors upon the process of acclimatization was determined, using twelve subjects divided into three equal groups. After the same preliminary training for all men, one group (A) continued to work in the temperate environment. The other two groups were taken into the hot environment and of these, Group B rested while the other (C) immediately undertook graded work which was progressively increased. When Group C was acclimatized (4th day) all three groups were subjected to the regular work schedule in the hot environment.

The comparative behavior of the three groups is striking. The subjects in Group C (with graded work in heat during the previous 3 days) had returned substantially to the normal physical state with only slight elevation of heart rate and temperature over the control levels. In contrast, the subjects in Group A, working in heat for the first time after extended preliminary training, gave no evidence of acclimatization, as shown by the high heart rate and body temperature. Only two of the four men completed the prescribed work and the condition of these two was considerably below that of the other men in the other groups.

The performance of the four men in Group B (resting in heat during the previous 3 days) fell between the other two groups. All four men completed the five work periods and, although the heart rate and body temperature were higher as compared with their control state, and also in comparison with Group C, the performance of these men was consistently better than that of the men in Group A. Thus, a partial state of acclimatization had been induced.

End #2

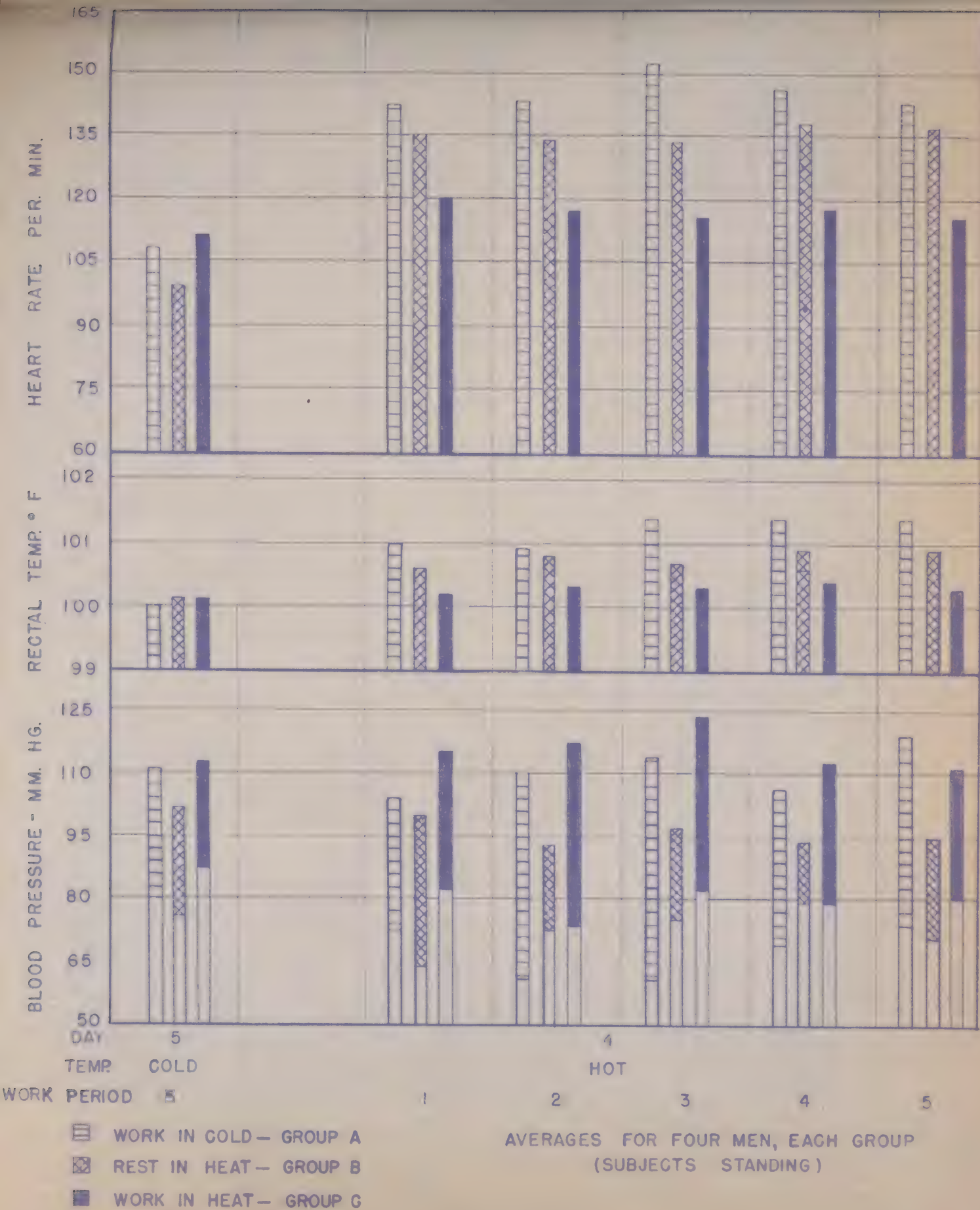


CHART-5




FLUSHING OF
FACE

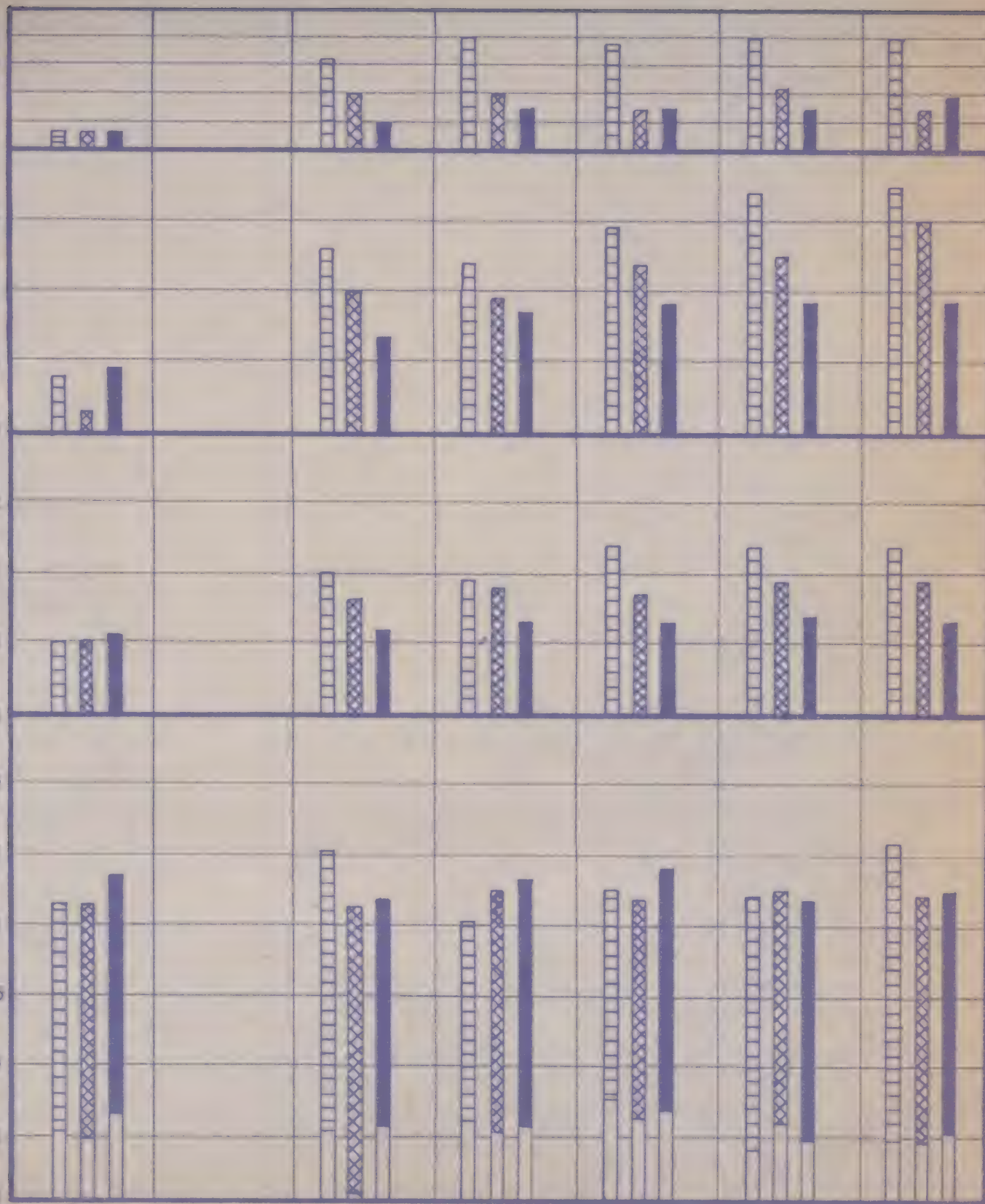
SEVERE
MARKED
MODERATE
SLIGHT

HEART RATE PER. MIN.

RECTAL TEMP °F

BLOOD PRESSURE — MM HG

DAY 5 4 3 2 1
TEMP COLD HOT
WORK PERIOD 5 1 2 3 4 5
AVERAGES OF 4 MEN, EACH GROUP —  WORK IN COLD  REST IN HEAT  WORK IN HEAT
(SUBJECTS LYING) CHART-6



4. Strenuous work from first exposure to heat (Chart 7) -

Strenuous work on first exposure to heat is not well tolerated. Twelve (12) unacclimatized men were asked to perform the full five work periods (12.5 miles) on their first day in the hot environment. Four men became exhausted (after the third or fourth period) and were unable to complete the task. The eight who completed the work did so with difficulty, finishing in poor shape and with high heart rates and rectal temperatures. The ability to complete strenuous work in the first exposure to heat does not necessarily indicate acclimatization nor the ability to continue to work in the heat. Maintaining work at a strenuous rate leads to progressive deterioration of performance. After two or three days many men become disabled and those who continue to work do so ineffectively and inefficiently. This is in contrast to the progressive improvement of men subjected to a schedule of gradually increasing work in heat. The performance of one of the subjects (Sub. Gee.) illustrates this point.

The data were obtained at the end of each work period of the last day in the cool environment and of each day in the heat. During the first day in the heat the man completed five work periods without much difficulty. On the second day in the heat, however, he completed only three work periods. On the third day he was forced to stop in the middle of the first period. It is of interest to note the low blood pressure on this day despite the more nearly normal rectal temperature and heart rate as compared with the fifth period on the first day in the heat at which time he was still in fair shape. After dropping out in the first period of the third day, this man rested the remainder of that day and drank plenty of water. On the next (4th) day he finished five work periods in good condition and with a heart rate and rectal temperature approximating those recorded after similar work in the cool environment. Despite the exhaustion resulting from too strenuous work during the first three days in the heat, this man had attained a large degree of acclimatization by the fourth day.

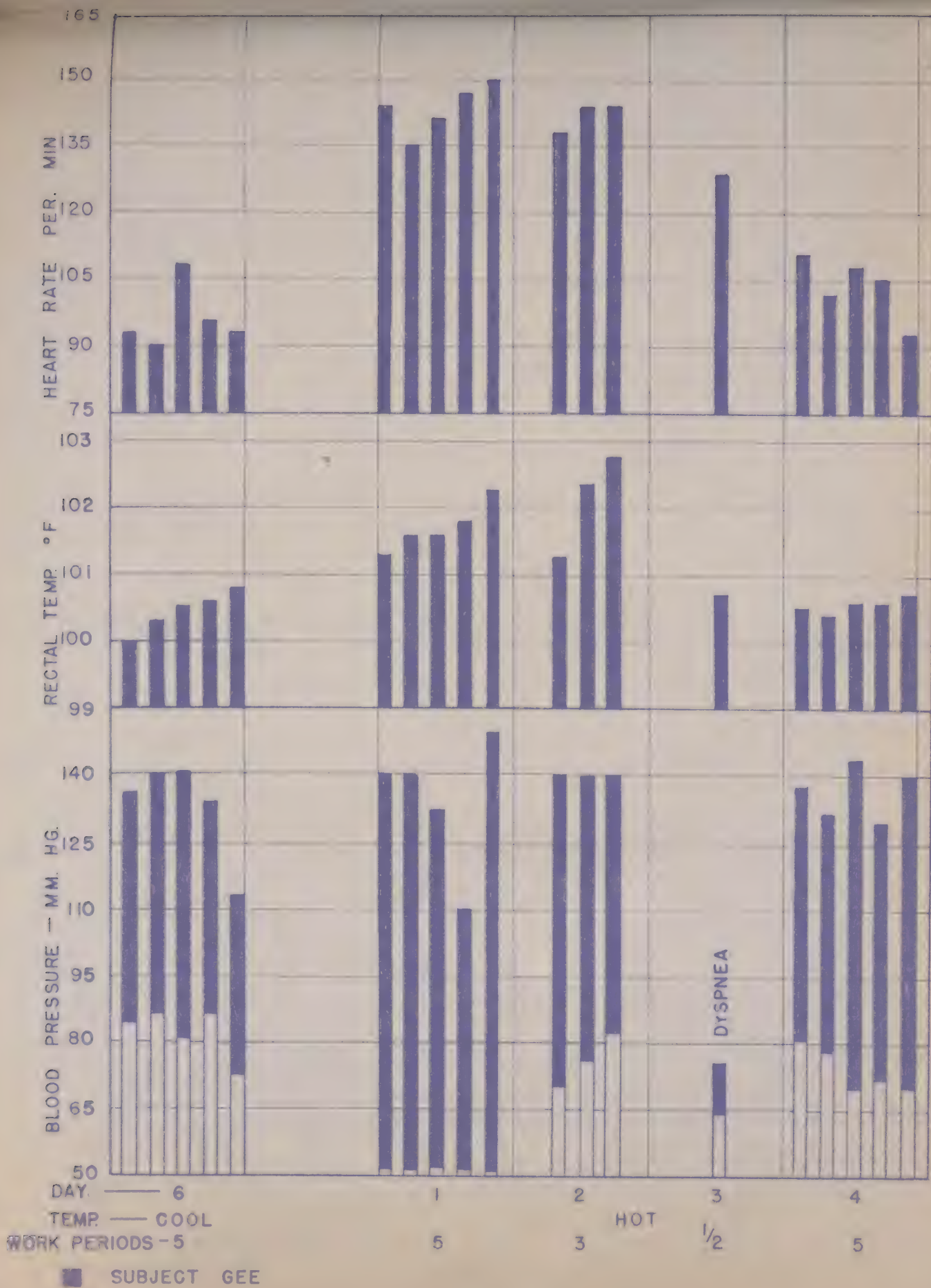


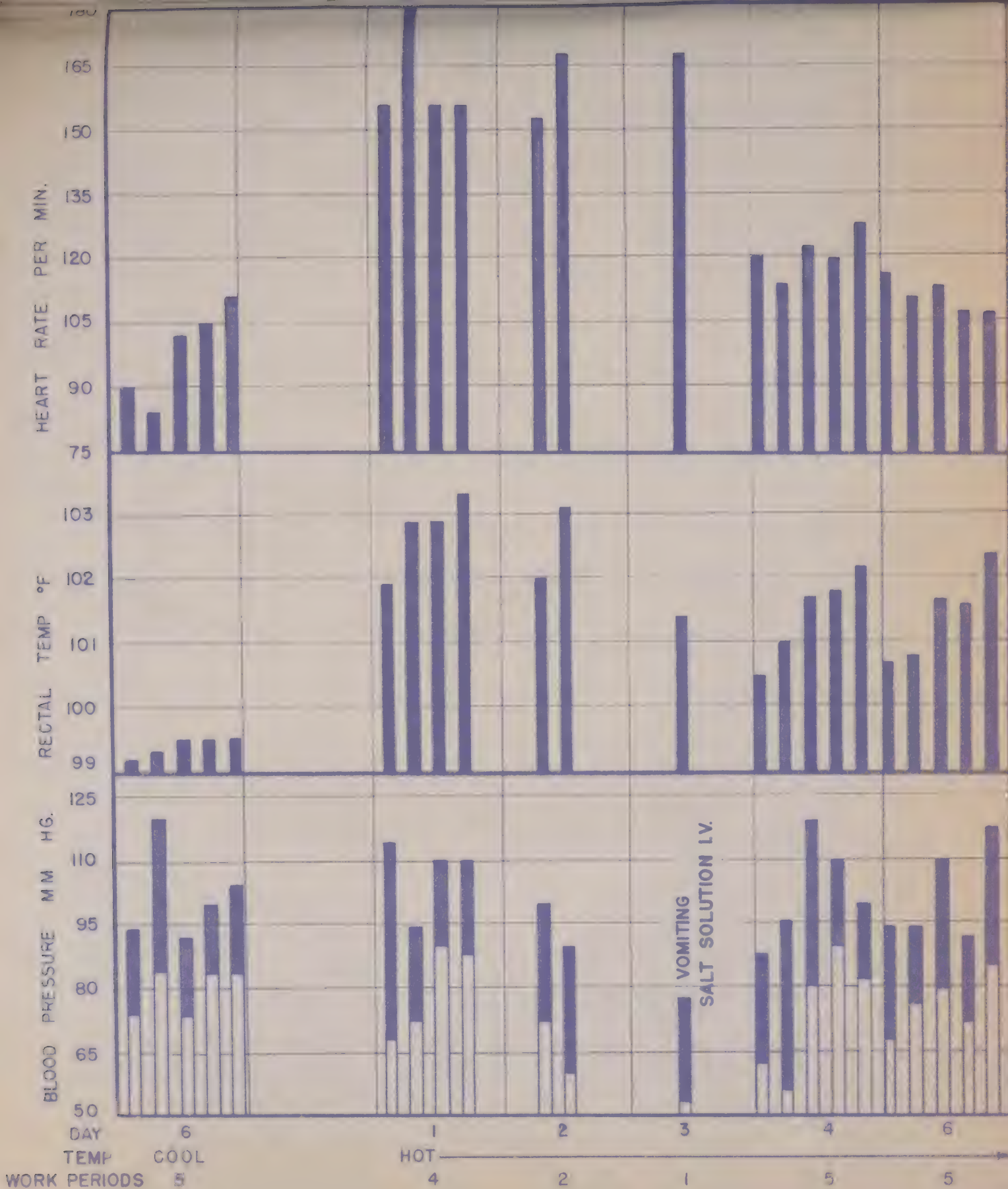
CHART-7



5. Intolerance to heat and heat exhaustion (Charts 7, 8) -

Development of symptoms of intolerance to heat and even heat exhaustion during the early days of exposure to heat do not retard the rate nor decrease the degree of acclimatization finally attained, provided that when such disability occurs work is discontinued, rest is permitted and water and salt are given. When work is resumed it should be within the capacity of the individual.

Chart 7, which illustrates this, has already been discussed. Chart 8 represents a similar, but more severe, situation in another subject. The data obtained at the end of each work period of each day in the heat are plotted and compared with the observations on the last day in the cool environment. On the first day in the heat this man could complete but four work periods when fatigue forced him to discontinue. On the second day he finished only two work periods; on the third day only one. Note the high heart rates and rectal temperatures reached on these days and the progressively decreasing blood pressure (Chart 8). The appearance and behavior of the subject indicated a parallel deterioration. On the third day this subject was quite ill; exhaustion, abdominal cramps, nausea, vomiting and marked apathy indicating heat exhaustion. After a litre of physiologic salt solution was administered intravenously the nausea, vomiting and abdominal cramps ceased. He rested for the remainder of that day and drank cooled (5.14) water copiously. On the next (4th) day and the days thereafter he completed five work periods without difficulty, always finishing strongly and appearing to be acclimatized. This improvement was accompanied by a reduction of the heart rate to values equalling those obtained in the cool environment but the rectal temperature continued to rise to high levels (102°F.).



■ SUBJECT SMI.

CHART-8

Single exposures to heat at intervals of three days (Cooper)

The following conclusions are based on data derived from eight subjects who performed two periods of work during a four hour exposure to heat every third day and who spent the intervening time in a cool environment: (1) A single relatively short period of work in the heat induces a little or no acclimatization, (2) a number of such exposures separated by two days in the cool environment results in acclimatization, (3) the major portion of the acclimatization for the above work requirements is produced by three or four such exposures to heat.

Representative observations on subject Mel., taken at the end of each work period during the four-hour exposures to heat are shown in Chart 9. During each exposure two periods of work were performed, separated by one hour of rest. The first exposure to heat was badly tolerated and caused weakness, nausea, vomiting and syncope when in the erect posture. The second exposure produced similar but less severe symptoms and vomiting was absent. Thereafter work in the heat was accomplished without difficulty and with increasing ease. The associated changes induced in the heart rate, rectal temperature and blood pressure and their regression paralleled the findings already described for subjects continuously exposed to the hot environment. (Compare Chart 9 with Charts 1 and 3) In this subject there was a particularly striking postural hypotension during the first three exposures to heat with a return of the blood pressure to normal as acclimatization developed.

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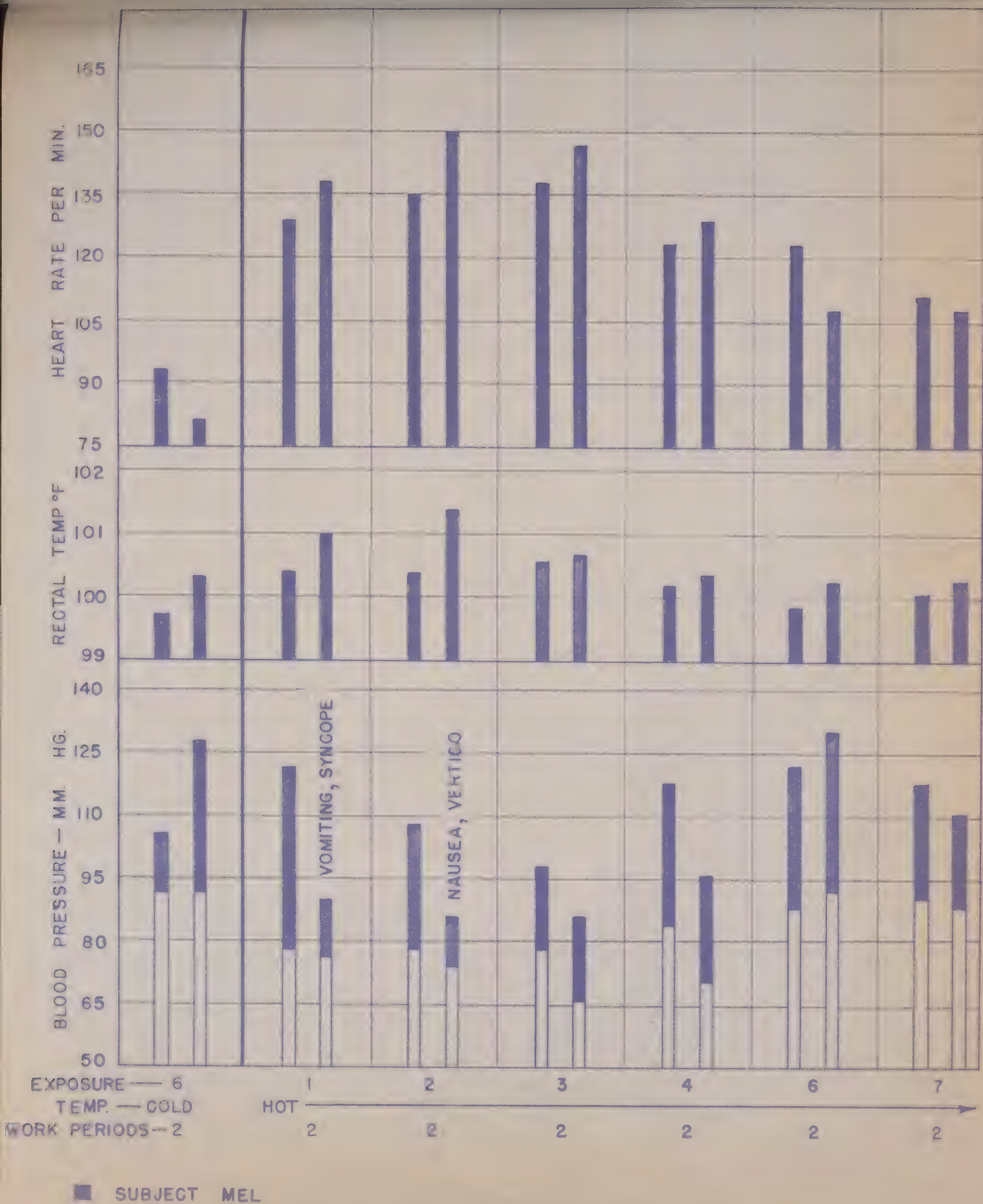
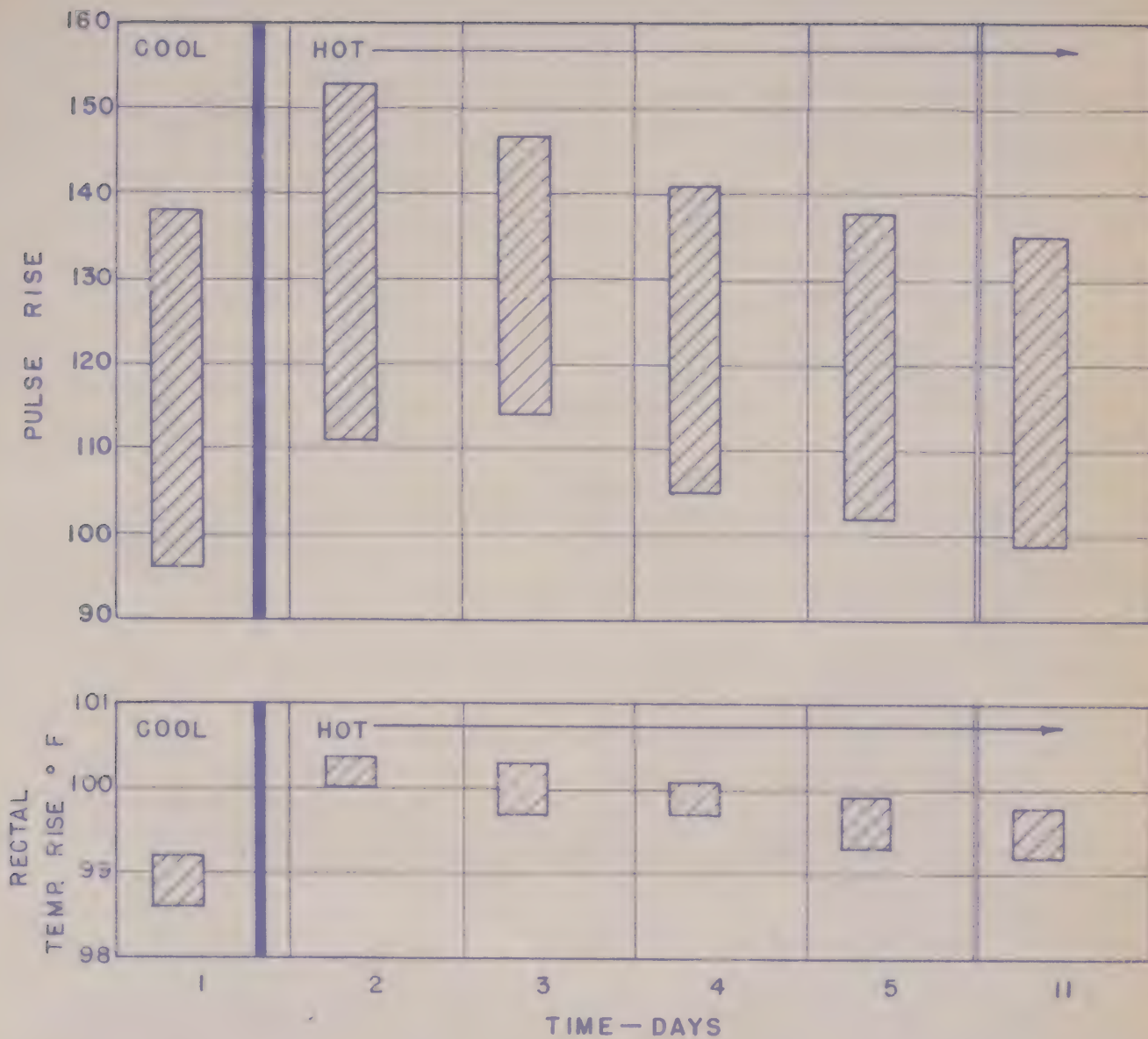


CHART-9

7. Short periods of severe exertion (Chart 10) -

The behavior of subjects performing severe work of short duration in the heat follows a pattern of change and readjustment similar to that for less severe work of long duration (marching). The severe exertion consisted of pedalling a stationary bicycle for ten minutes each hour. The plotted observations are for one subject taken at the end of the first "ride" of each day.

The high rectal temperatures and pulse rates produced by this exertion become successively less marked as work in the heat is continued. Levelling off is attained by the fourth or fifth day. In one respect the readjustment differs from that observed for the more moderate work of marching. The resting level, rather than the increase caused by work, determines the final level of the pulse rate and body temperature. Most subjects found these short bouts of severe exertion less fatiguing than the prolonged but moderate work of marching.



EFFECT OF TEN MINUTES OF BICYCLING IN A TRAINED SUBJECT

8. Rest at night (Chart 11) -

Adequate rest at night is essential for good work performance in the heat, even in acclimatized men. Deprived of it, men work inefficiently the next day.

The data obtained on subject Mel. after the last (second) work period of each day are given. This subject belonged to that group which performed two periods of work during a four hour exposure to heat every third day. The night before his fifth exposure he failed to obtain adequate rest. His performance during the next day was almost as poor as that on the first exposure to heat and he completed the work with difficulty. Here again the true state of the subject is not indicated by the heart rate and rectal temperature. During the fifth exposure they are higher than during the first and second, yet the subject was in a better condition. There was no headache, nausea, vomiting or syncope in the erect posture, occurrences which had rendered him totally incapable of further effort on the first day in the heat.

The poor performance during the fifth exposure to heat did not retard further improvement. Note the much improved performance during the sixth exposure.

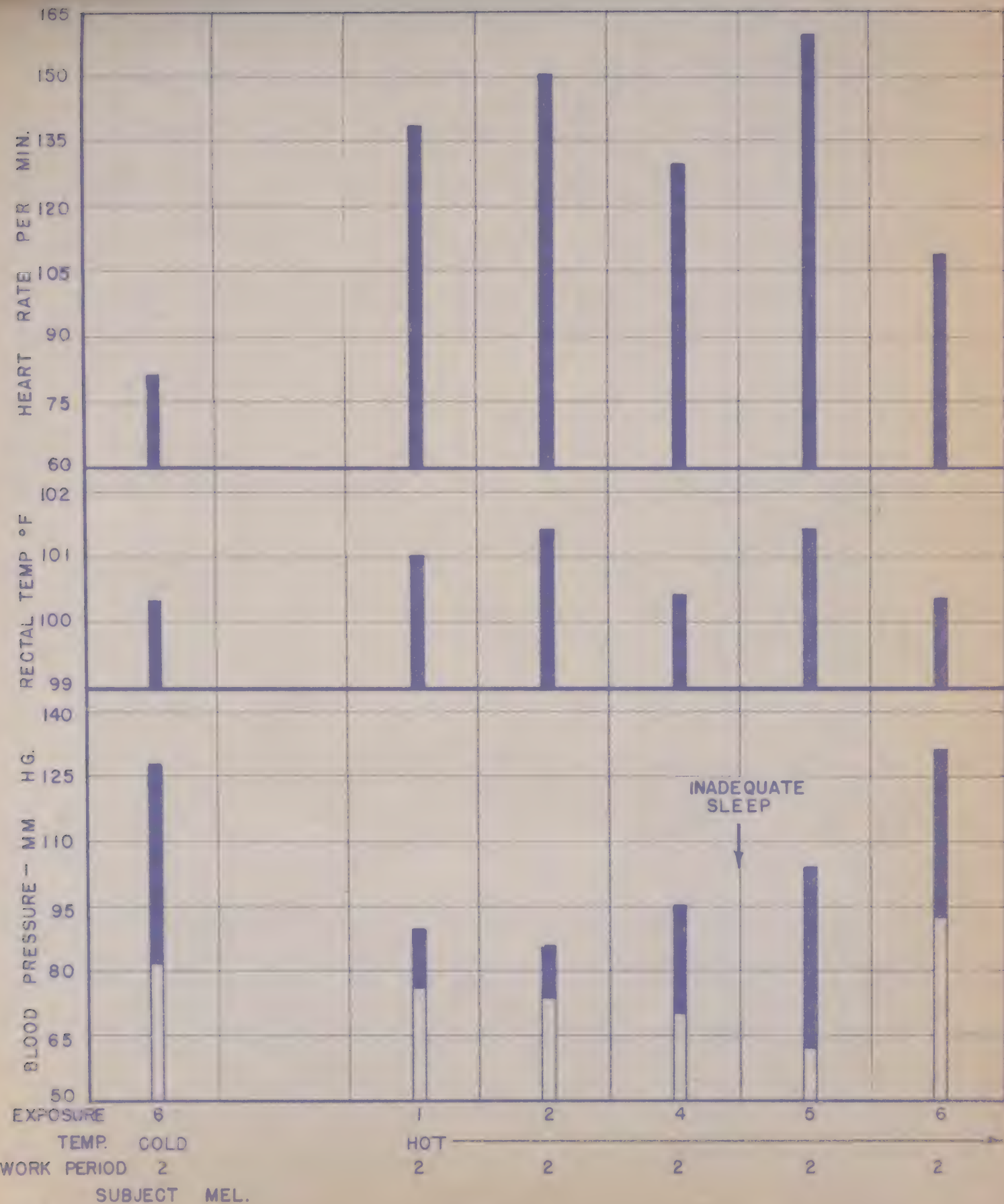


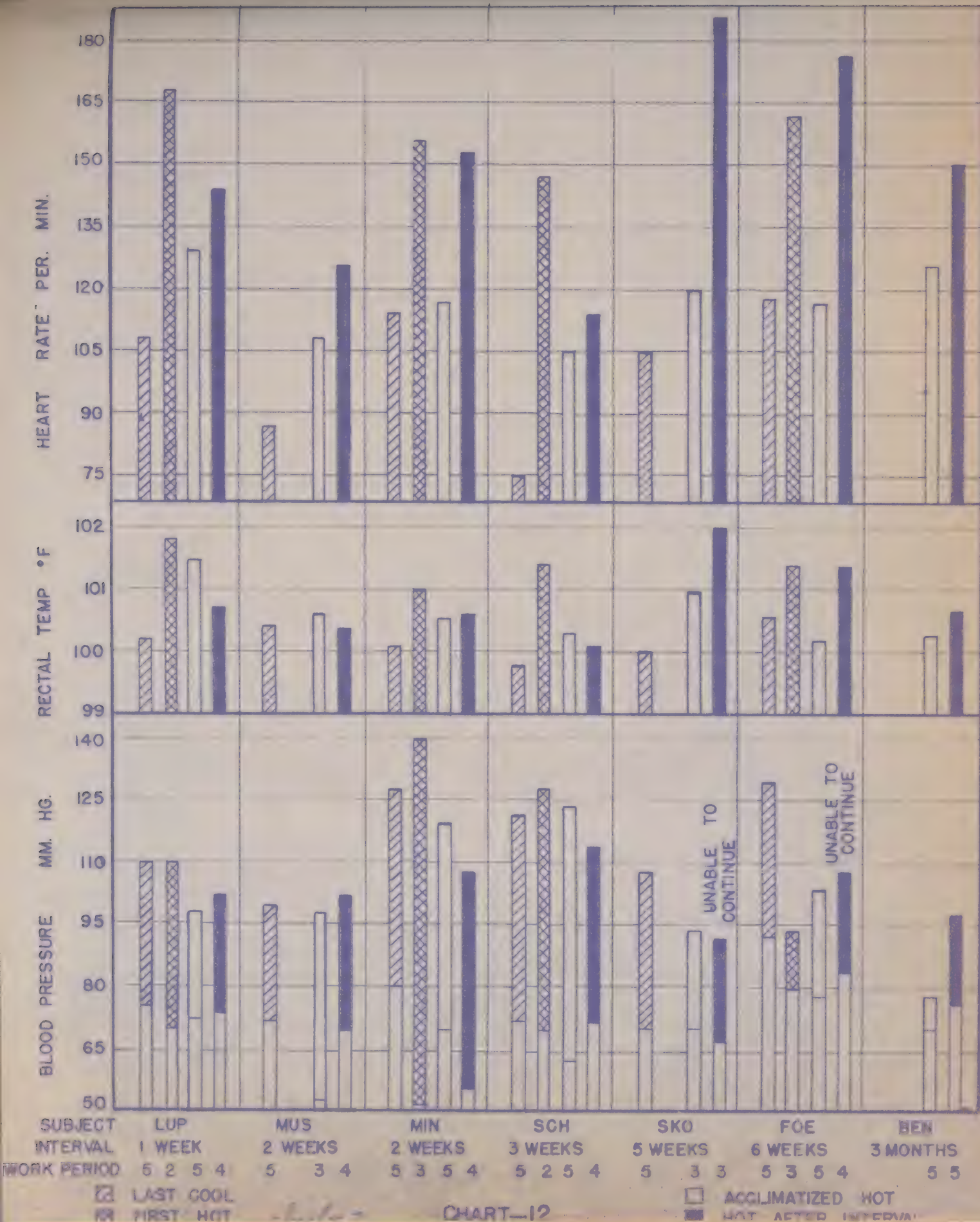
CHART-II

9. Duration of acclimatization (Chart 12) -

Acclimatization to desert heat after removal from the hot environment is well retained for at least one week and probably for two weeks. Thereafter, a variable but more rapid loss ensues so that after one month the major portion of the acclimatization is lost by most men. Some men, however, retained a considerable degree of acclimatization for two months after leaving the hot environment.

The plotted data were obtained on seven men at the close of the last work period on their first re-exposure to heat (solid column). These are compared with the observations made at the end of the last work period, on the last day in the cool environment (diagonal-lined column), with the first day in the hot environment (cross hatched column), and when fully acclimatized (open-block column). The observations for each individual are grouped together and separated by long vertical lines. "Interval" indicates the time between leaving the hot environment and first re-exposure to it.

The sharp loss in acclimatization after three weeks was indicated not only by the high heart rates and rectal temperatures (Sko., Foo., Ben.) but also by the failure to complete as many work periods and by the poor appearance of the subject. The vigorous and alert appearance of subjects Lup., Min., and Aus., and the ease with which they completed their prescribed work indicated a high degree of acclimatization despite their higher heart rates and rectal temperatures. Subject Sch. worked as well in the heat after a lapse of three weeks as when fully acclimatized.



10. Maintenance of acclimatization (Charts 12A, 13) -

There are two requisites for the maintenance of a high degree of acclimatization to heat over a long period of time: a., the maintenance of good physical fitness and b., repeated exposures to heat, preferably with work, at intervals of one month or less.

Of the three subjects considered in Chart 12A, subject S was never in good physical condition, subject M remained moderately fit and subject W only fairly so. The strikingly poor performance of subject S when he walked in the heat after a lapse of 37 days indicated that he had not only lost all of his acclimatization but was in far worse condition than at any previous time. This was attributed to loss of fitness as well as of acclimatization in the interval.

The more fit subject (M) had a much better work performance than the less fit subject (W) when re-exposed to heat after a lapse of 16 days and 37 days. This was indicated not only by the lower heart rate and rectal temperature of subject M but also by the fact that of the three men re-exposed to heat after a lapse of 37 days he was the only one able to complete the full five work periods.

The need for re-exposure to heat in order to maintain acclimatization is indicated in Chart 13. Here are plotted the observations made on one subject at the close of each work period on the last (5th) day in the cool environment, on the first four days in the hot environment, and on re-exposure to heat 44 and again 47 days after leaving the hot environment. Initial acclimatization to heat was rapid and by the third day, five work periods were performed without difficulty and with heart rate, rectal temperature and blood pressure approximating those for the cool environment. On the first re-exposure to heat 44 days after leaving the hot environment, the subject was unable to continue after the fourth work period. At that time he was almost exhausted, the heart rate was more rapid than at any other time and the rectal temperature was high. But this exposure re-induced a great deal of acclimatization. During another exposure to heat three days later he was able to work as long and almost as efficiently as he had done when well acclimatized to heat 47 days previously.

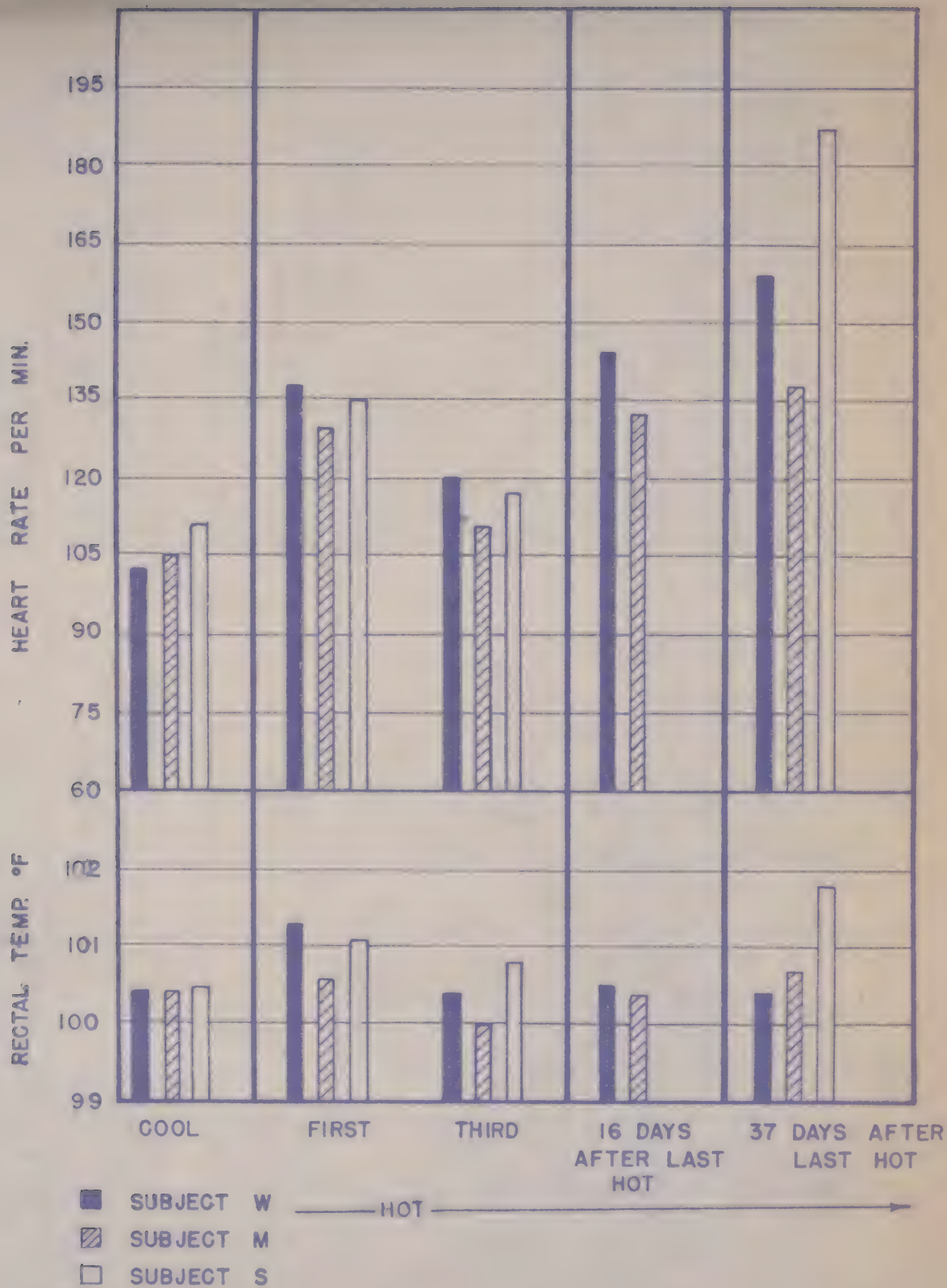


Chart #2

CHART—12A

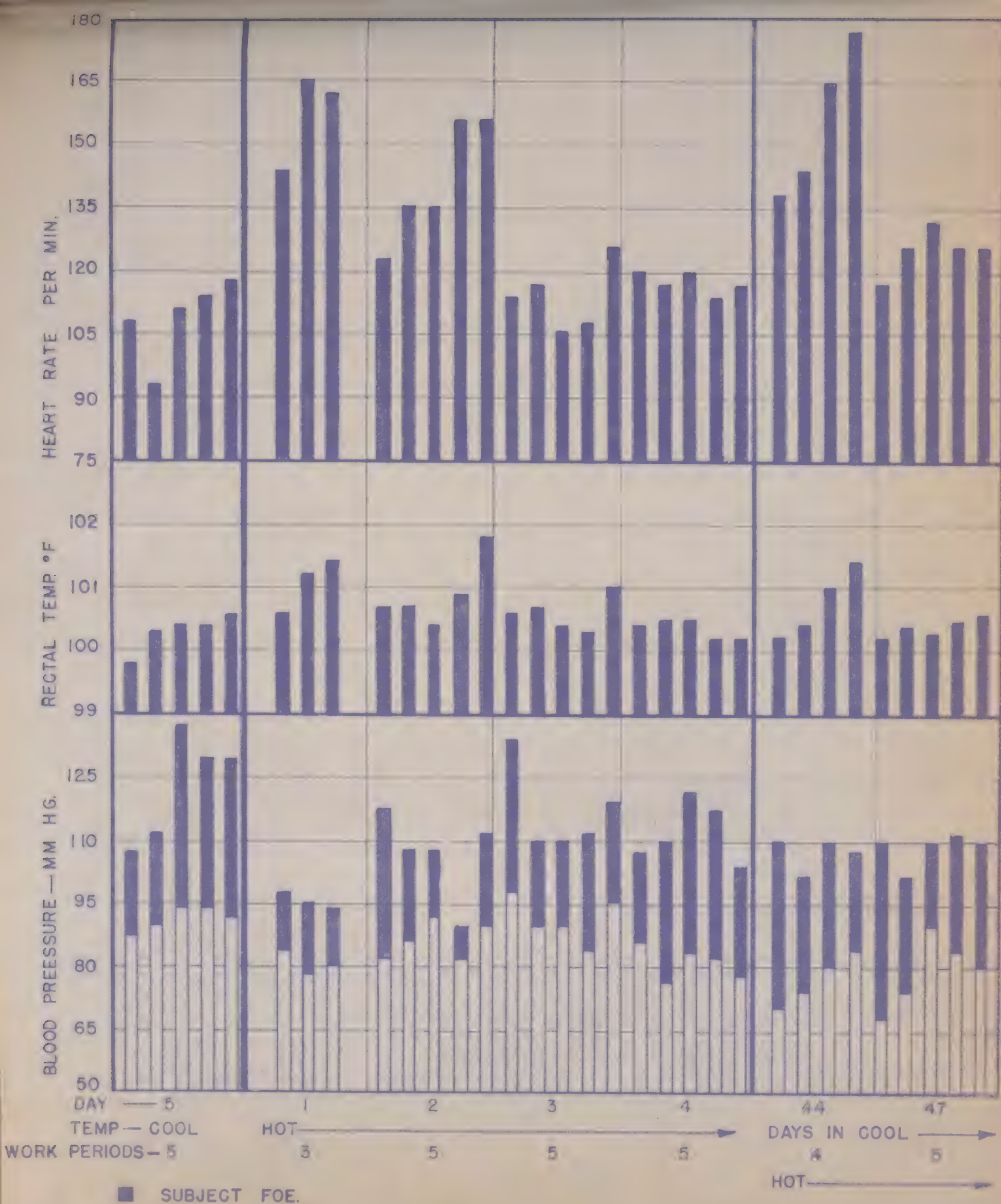


CHART-13



11. Increased water intake (Chart 14) -

Thirst is an inadequate guide to the fluid required for work in the heat. No men drank enough water voluntarily to replace that lost in the sweat while working and all developed water deficits. Increasing the water intake during work to an amount (1200 ml per hour) equal to the water lost by sweating increased the amount of work which was accomplished on the first exposure to heat.

Twelve men were asked to work the full five periods during their first day in the hot room. Nine men received water in amounts sufficient to quench their thirst (600 ml per hour), 3 received water in amounts (1200 ml per hour) equal to the weight (sweat) lost. These ~~three men all finished the five work periods without great difficulty.~~ In contrast, four of the other nine men became exhausted after three or four work periods and could not continue. Those who did finish were in poorer condition than the men whose water intake was intentionally increased.

In chart 14 one may compare the effects of slight water restriction (6 litres per day), and of full water replacement (9 litres per day), on two groups of three men each, in their first and fourth days in the hot environment. Each column represents the averaged data for the group. Observations were made at the close of each of the five work periods for the last day in the cool environment and the first day in the hot environment. Observations are also recorded for the fourth day of heat exposure when both groups were permitted to drink as much water as they chose. Men who did not complete five full periods have been excluded.

Although the group in which water was forced to full replacement showed smaller disturbances of vigor, behavior, pulse rate and rectal temperature during their first day in the heat, the degree of acclimatization attained by both groups on the fourth day was the same.

Sub #2

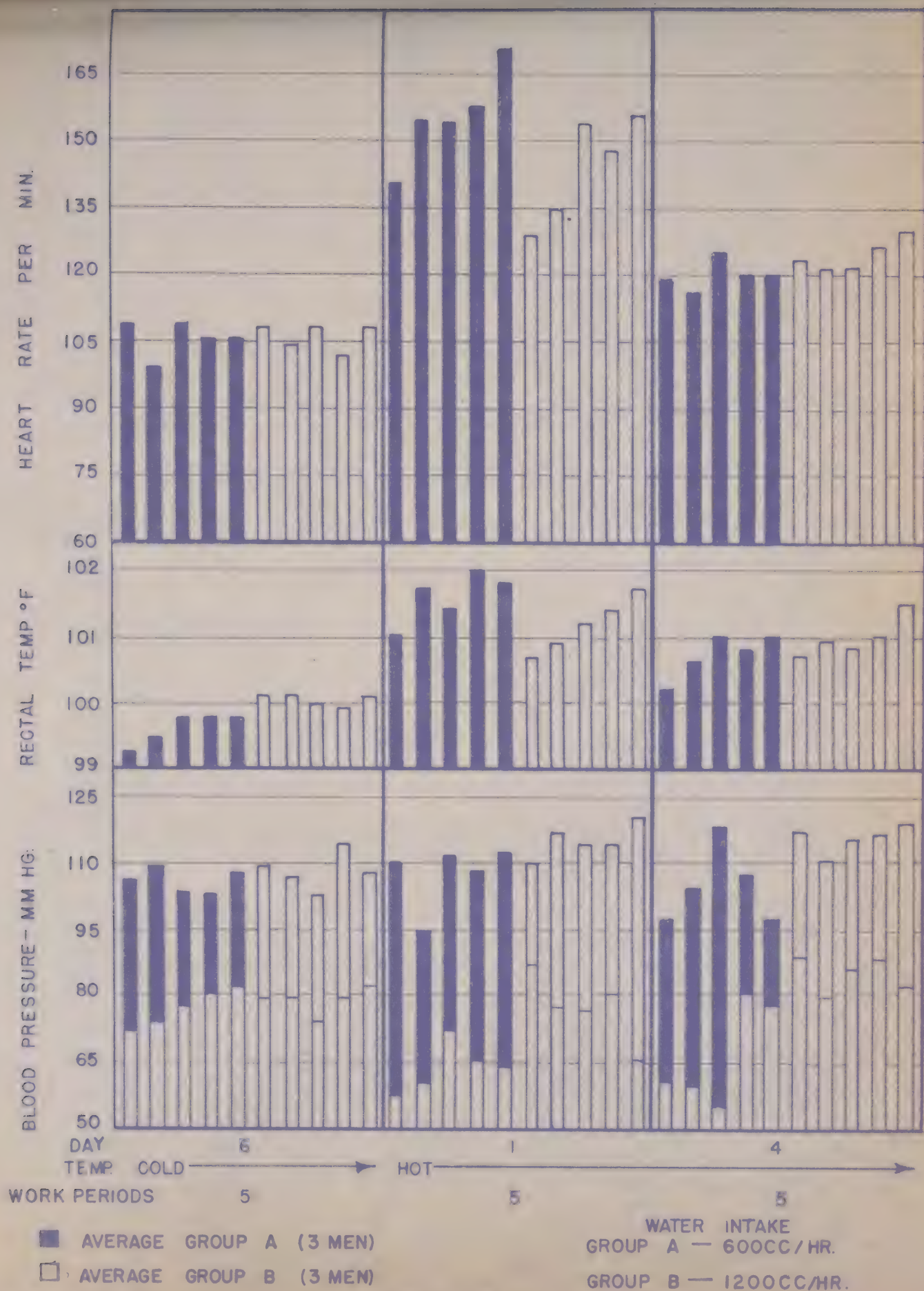


CHART-14

12. Water restriction (Chart 15) -

Sudden restriction of the water intake of well-acclimatized men at work to one-half of the optimal requirement induces changes similar to those which appeared in the men on first exposure to heat when they were unacclimatized.

In Chart 15 are plotted observations made on each of four well-acclimatized men. Their performance at the close of each work period on the day (9th) when water was restricted to 4 litres per day is compared with that following the fifth work period on a day (4th) when they received as much water as they desired. Subject Nor. was incapable of continuing after the third period and the other men finished five periods with difficulty. Note the higher pulse rates and rectal temperatures and the low blood pressures.

Important changes which the chart does not show is the condition of the men, their low morale and lack of vigor, their glassy eyes, their apathetic, torpid appearance, their "don't-give-a-damn-for-anything" attitude, their uncoordinated stumbling, shuffling gait. Some were incapable of sustained purposeful action and were not fit for work, let alone battle. All they wanted to do was rest and drink.

Progressive restriction of water was tolerated better than sudden restriction. For sudden restriction the intake was reduced on 1 day to 4 litres. Progressive restriction was carried out by limiting the intake from the optimum level of 8 L/day to 6 L for the first day, 5 L for the second and third day and to 4 L for the fourth day. The gradual restriction of water intake resulted in physiologic disturbances similar but less severe than those observed from sudden water restriction. Men were incapable of performing as much work as when water intake was adequate.

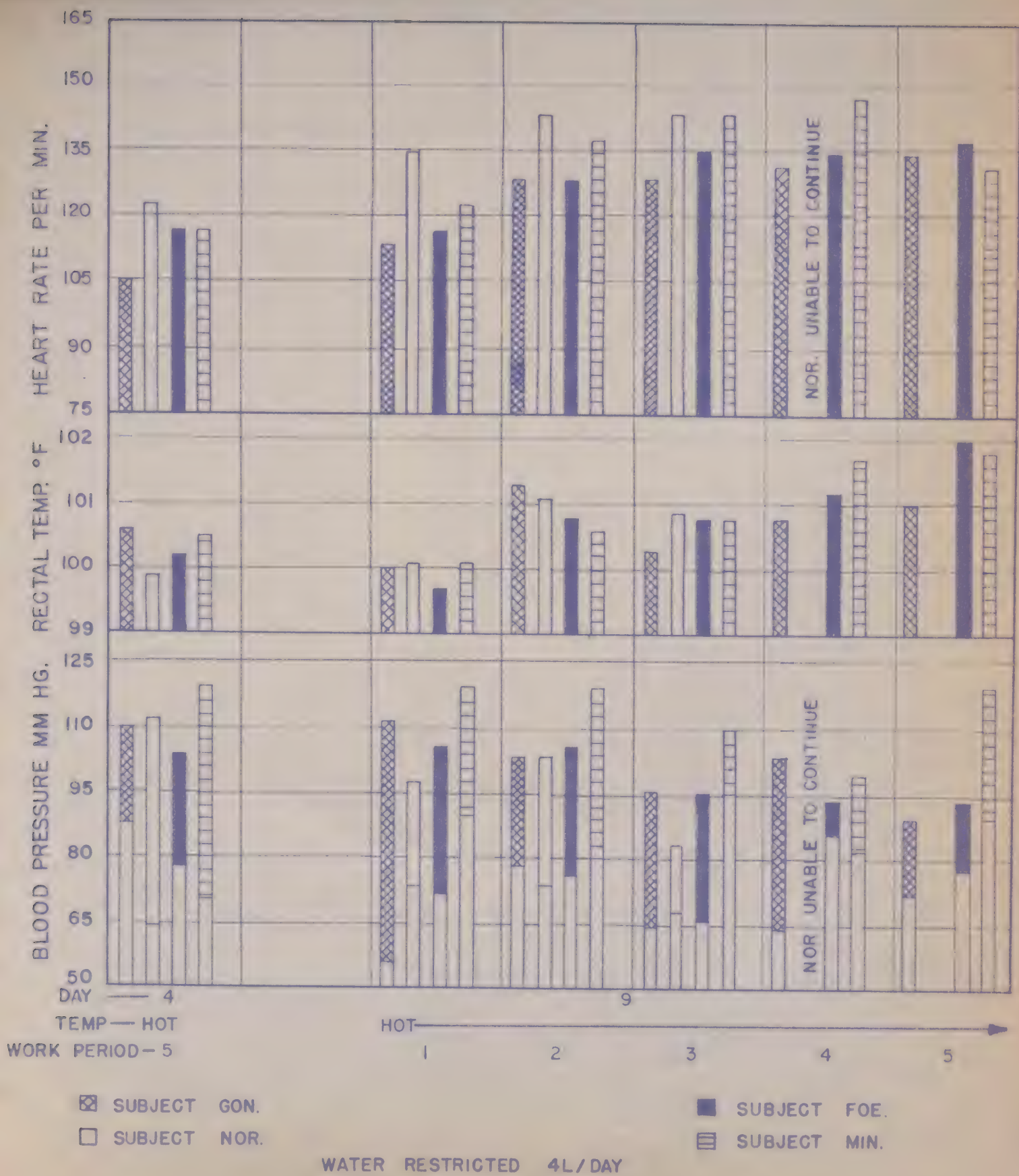


CHART-15

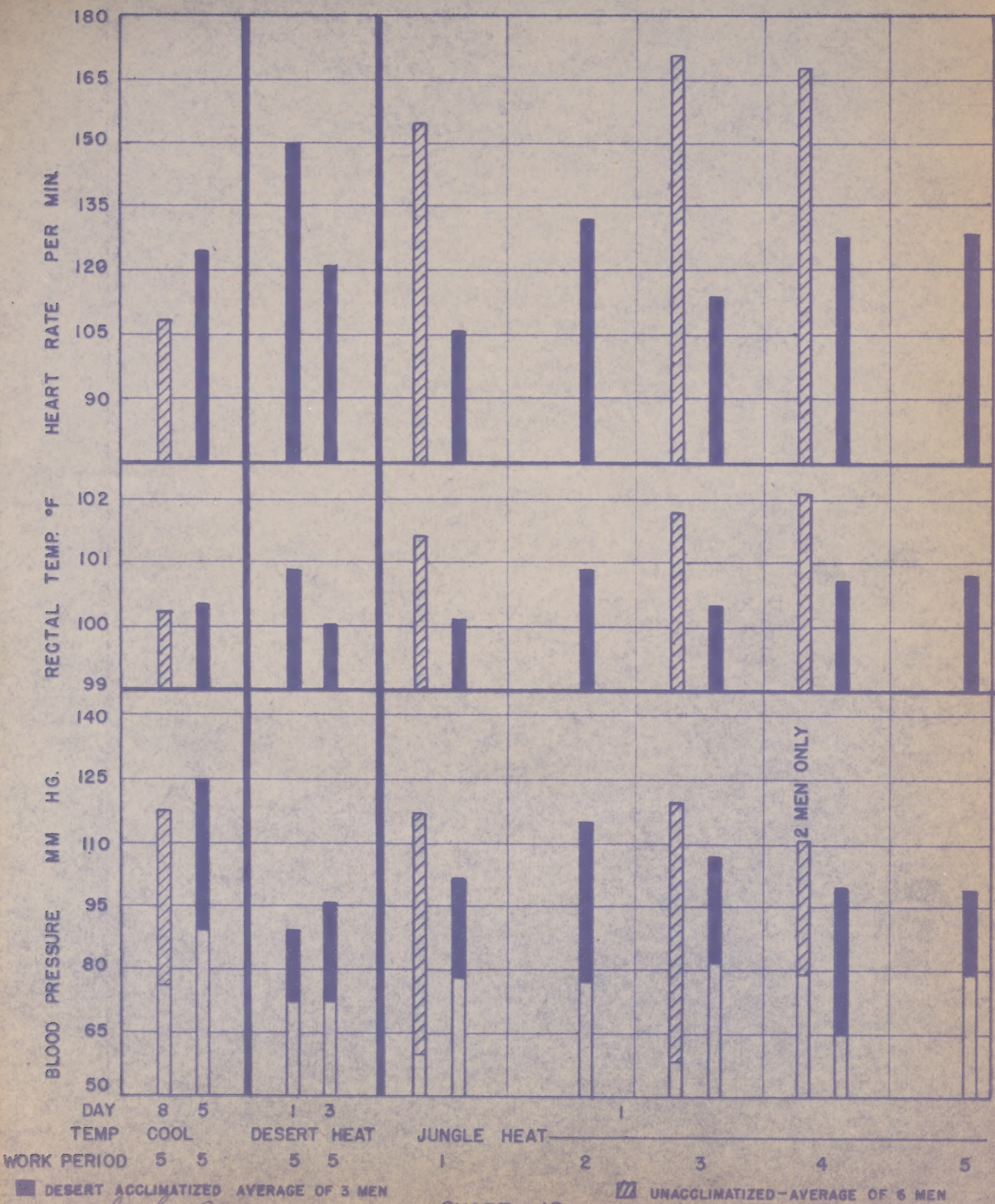
13. Cross acclimatization to jungle heat (Chart 16) -

Acclimatization to dry (desert) heat increases markedly the ability of men to work efficiently and effectively in hot moist (jungle) environment.

Three men were fully acclimatized to desert heat and six men were trained to work in a cool environment. All nine men then worked in a simulated jungle environment; dry bulb 90°F to 91°F, wet bulb 80°F to 87°F, relative humidity 70% to 76%. The averages of the data obtained on each group of men at the close of the last work period in the cool environment, and at the end of each work period of the first day in the hot moist (jungle) environment are compared. The performance in desert heat, (as expressed by average data for the desert group) is plotted between the heavy vertical lines. The first column represents observations made at the close of the fifth work period of the first day in the heat, the second column, the data from the fifth work period of the third day, when acclimatized.

On the first day in hot moist (jungle) heat five work periods were completed by each of the desert-acclimatized men; two men finishing strongly and easily and the third with some difficulty. Of the six men not previously exposed to a hot environment, four were able to complete only two periods of work, the first and third, while the other two completed three, the first, third, and fourth. Not only were the desert-acclimatized men capable of a greater work output but the work was performed more efficiently than was the smaller amount of work done by the other men.

The performance of the desert-acclimatized men, however, was poorer than it had been in the cool and desert environments.



CHART—16

14. Results of special tests -

a. Basal metabolic rates did not change significantly during the process of acclimatization.

b. Electrocardiographic changes associated with work and change in position were the same with the subjects in the heat as they were when the subjects were in normal temperatures.

c. Vital capacity was not affected by acclimatization.

d. Code aptitude tests and attention tests showed a decrease in scores on the first day in the heat, and a gradual return to the control levels during the next three days. The initial decreases amounted to about 15%. All men were affected by an obvious depression in the heat for the first day and some instances for three days.

